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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

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Forthcoming Events.

SEPTEMBER 4-7.

Institute of Metals:—Annual autumn meeting at Liverpool.

SEPTEMBER 5-12.

British Association for the Advancement of Science:—Meeting at Glasgow.

SEPTEMBER 5-22.

Machine Tool and Engineering Exhibition at Olympia, London.

SEPTEMBER 13-14.

The Ceramic Society:—Autumn meeting in Glasgow of the Refractory Materials Section.

SEPTEMBER 14-16.

Association of Special Libraries and Information Bureaux:—Annual conference at New Oxford College, Oxford.

SEPTEMBER 22-27.

Iron and Steel Institute:—Autumn meeting at Bilbao.

SEPTEMBER 24-OCTOBER 6.

World Power Conference:—Fuel conference at Imperial Institute, London.

Union is Strength.

In the course of his remarks, one of the speakers at the banquet held at the Leicester Conference touched on a point of great importance. Speaking as an engineer, he said that he has frequently had occasion to consider whether, in that capacity, he should make castings or not. He had come to the conclusion that making castings was not his job, and that it was both better and cheaper for him to buy from specialist foundries.

We touch here, of course, on one of the main problems of the foundry trade. Obviously the same solution cannot suit every engineering works. There are problems of special and exclusive designs, problems of delivery, and many other considerations that may well compel a works to set up a foundry, although its primary object is to make, not castings, but products of which castings only form part. It cannot be denied that there are many such works throughout the country which have foundries second to none, whether in point of work, enterprise, or far-sightedness. For the jobbing foundry has its own difficulties, not the least of which lies in the very variety of its work, and if a foundry develops on a specialised line there is obviously every reason for a financial link between it and the works which absorbs its specialised output.

We thus find foundries in a wide variety of works and establishments, and founding becomes what may be termed an auxiliary process. It is of vital importance to engineering, and this very importance deprives it of that detachment and exclusiveness which is to be found in many other industries. The textile trade, or paper-making, for instance, are other examples of process industries. They, too, take a raw material—which in our own case is pig-iron—at one stage of its conversion process, and they change it, with the aid of other raw materials—in our case again, coke, sand, limestone—into something else, such as castings. The finished product of the founder is still only the raw material of the engineer. But these other industries present a united front to users, to buyers, and to competitors. They have powerful manufacturers' associations which are in a position to act for the common good. The foundry trade, on the other hand, is so widespread and so scattered that many people who run foundries as an essential part of their business do not regard themselves as founders at all. They look upon founding as an incidental process, like galvanising or soldering or smithing, and their major interests lie elsewhere.

But it is vitally important to induce in them a consciousness that they are, in fact, founders. How is it to be done? How is the maker of, say, calculating machines to be brought to learn that founding is a highly specialised craft demanding experience and technical knowledge? Or that it is expanding every day? Or that the followers of this craft have to be managed with a sympathetic understanding of these facts instead of being regarded as some sort of a necessary evil, an evil only to be tolerated because it cannot be abolished? The fact is that a large number of such men are not, if the term be permissible, "foundry-conscious," and hence they deprive founding as a whole of their very considerable strength.

Die Castings or Precision Sand Castings?

At the Liverpool meeting of the Institute of Metals much consideration was given to the question of die castings. It has been the subject of research at Woolwich Research Department, the National Physical Laboratory, and the University of Sheffield. The average non-ferrous founder has repeatedly to decide as to the desirability of extending his well-established business to embrace die castings. The governing factor is essentially the number of castings likely to be ordered before the design is changed. So far the problem is relatively simple. But even when a die castings department is well established, and the behaviour of the alloys used is throughly understood, there still remains for every complicated casting an experimental period, which will consume "x" number of man-hours and "y" £'s worth of fuel before success is attained. Though the most skilled workman or gang of workmen may be transferred to the new job, yet there will be a period of apprenticeship of unknown duration. We have known a whole week to be expended before achieving first-class results. We assert that for some individual die-cast jobs, the skill demanded from the operative is equal to that for which in some spheres of life a full apprenticeship is called for.

Whilst we should be the last persons to discourage any founders from taking up this fascinating department of foundry practice, we would suggest that they should first so develop the manufacture of precision sand-cast articles that there will be a retardation on the part of engineers to specify die casting. By the use of modern moulding machinery, and oil-sand cores, a competition can be established which will ensure that each section maintains and develops what is definitely its own economic field. Obviously there will always be border-line jobs, and if we had to arbitrate we should favour the sand-cast proposition on account of lower capital outlay and lower experimental costs.

Moreover, experience has indicated that the majority of engineers are at any moment liable to receive an added brain wave necessitating an alteration of design, and to effect this on a well-finished metal pattern is generally costly, but to carry out modifications on dies can be prohibitive.

Experimental research metallurgists show a partiality to die-castings, because their pet alloys invariably show up better when so cast. Perhaps it is because the more erudite amongst the founders have included this branch in the manufactures, and thus research work is assured of a more sympathetic reception.

XUM

A New British Chemical Standard Aluminium Alloy.

The second of a series of non-ferrous standard analysed samples is now ready for issue.

The analysis is as follows:—

Aluminium Alloy "A."

	Per cent.
Copper	4.68
Zinc	2.37
Nickel	1.85
Lead	1.51
Magnesium	1.34
Iron	0.51
Silicon	0.39
Manganese	trace
Tin	0.05
Aluminium	87.30
	100.00

This standard has been prepared in response to an appeal made at the last triennial meeting of co-operators in the movement and arising out of the growing use of aluminium alloys in the aero, motor, and other industries. It will enable chemists to check their methods of analysis and individual working, and thus to settle disputes between buyers and sellers.

The composition does not correspond to any one recognised specification, but is a compromise to enable it to be analysed concurrently with most of the B.E.S.A. alloys, such as L11, L8, L5, L24, also the other alloys containing copper, zinc, nickel, magnesium, etc.

As usual, the analyses have been undertaken by a number of chemists having special experience in this class of alloy, *e.g.*, referee analysts, manufacturers, users, and government departments. The standard is available to anyone at a price based on covering the cost of preparing and issuing it. The three usual sizes of 50 gr., 100 gr., and 500 gr. are provided, and a certificate (1st edition), giving the names of the analysts collaborating and their analyses, is furnished with each sample. In a later edition an outline of the methods employed will be included and sent on request in exchange for the first edition. For further particulars apply to the headquarters, 3, Wilson St., Middlesbrough.

The Machine Tool and Engineering Exhibition.

This Exhibition, which was opened yesterday, is the fourth of the series, and like its predecessors is of considerable interest to the foundry. Not only are the major portion of the exhibitors themselves founders, but a section of the exhibition is designed to interest the patternmaker. Moreover, there is a large consumption of small tools in the foundry industry, such as tool steel, vices, hack saws, and the like. Patternmaking tools are being shown, but not in such large quantities as we would have expected. An important phase of the foundry industry, that of grinding, is well represented. We strongly advise all our readers to visit Olympia before the exhibition closes on September 22, bearing two factors in mind. They will see the demands required from them by the latest advances in machine-tool practice, and have placed before them a number of auxiliaries for the better running of their shops.

Tramway Rails for Birkenhead.

Messrs. Bolckow, Vaughan & Company, Limited, have received an order from the Birkenhead Corporation for 150 tons of B.S.S. No. 8 high-silicon tramway rails and fishplates.

The National Light Castings Employers' Federation and the Joint Committee of the Light Castings Trade Unions have been in negotiation respecting a proposed wages reduction, and at a recent conference in Glasgow the Joint Committee agreed to submit certain terms to a ballot of the men. The result has now been made known, and shows a majority of 690 in favour of acceptance.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Theory and Practice.

To the Editor of The Foundry Trade Journal.

Sir,—In view of recent discussion and correspondence in connection with Mr. John Shaw's paper, etc., the translation of a Paper from "Die Giesserei" on graphite in grey cast iron and its influence on mechanical properties, on page 133 of your issue of August 23, is an interesting illustration of theories which can be formed based on laboratory work which are not applicable in bulk. For instance, on page 134, top of column 3, without giving any proof, the following statement is made, "it is better to alloy white iron in the molten state than to use graphite iron without superheating it." In regard to the question of superheating, I have from the first asked myself the question, why superheat when this is totally unnecessary? Arising out of this my views are now well known that at least for important work it is better to use pig-iron in which the constituents, including carbon, will go into solution at ordinary temperatures met with in foundries, than specially to superheat in order to get the impurities into solution; as by the former practice melting practice in the foundry is made as foolproof as possible. Make work easier, not more intricate.

It is also interesting to read the further statement of results on bars 1.18 in. dia., one of which was cast in sand and allowed to cool naturally, whilst the other was cast into chills and immediately afterwards drastically annealed. In the former case the bar would be slightly more open or "greyer" in the centre than on the skin, whilst the latter after annealing would be more open or greyer on the skin than in the centre. Yet from these two structures the one obtained naturally and the other not naturally, the conclusion is drawn that the size of the graphite is of *primary* importance, for the mechanical properties. With so many other possible variables it is quite inconceivable that any such conclusion should be drawn. The two things are not comparable for *industrial* application.

It is next stated that the matrix of the sand cast bars are pearlitic, whilst the chilled bars were ferritic, which bare statement upsets natural law applied to chill, as known in the foundry from some unknown period up to the present time. This is a misleading statement. What should have been stated is that when certain bars are cast in sand and allowed to cool normally the structure is pearlitic, whilst if they are cast into a chill of a certain kind, and before cooling drastically annealed, the matrix is ferritic, then practical men, at any rate, would have stated that is just what we would have expected. Nothing new!

Again Fig. 5 is not comparable for the reason just given, and therefore whilst the results are of academic interest it would be unwise to attempt to apply certain of the conclusions to foundry practice, as there is certainly considerable risk of doing.—Yours, etc.,

E. Adamson.

18, York Street, Sheffield,
September 3, 1928.

[This letter has been slightly abridged.—Ed.]

The Capponfield Furnaces.

Further to our note last week that the Capponfield furnaces have been relit, it is interesting to note that it is about seven years since they last made iron. Three grades are to be produced—hot blast, warm blast and cold blast. The warm and hot will be fairly low in phosphorus, say 0.5 per cent. By slow working it is sought to produce a superior grade of iron, somewhat lower in total carbon than usual, and so be suitable for the production of high-grade engineering castings.

Random Shots.

I have had to stand up to a good deal of argument about the views I put forward last week on the influence of machinery on unemployment, but I must confess that up to date my views have not been shaken. One interesting sidelight on the whole problem was raised to this effect; our very ability as a nation to carry the enormous weight of taxation under which we groan shows that our efficiency as a producing nation is at any rate no worse than it was before the war, however it may compare with that of our competitors.

* * *

During the war large numbers of women were introduced into industry for the first time, and while these have to some extent been replaced by men, there is little doubt that the number of women employed to-day is much greater than has ever been the case before.

* * *

Assuming over-all increase in efficiency and a certain amount of displacement of men by women, is it not likely that we can afford to regard the unemployed as a sort of leisured class, a class of displaced persons, under present conditions not capable of re-absorption? It does not seem unreasonable to argue that the more efficient industry becomes and the greater the rate at which the industrial machine produces, the smaller will be the number of people required to take part in industrial production.

* * *

Alternatively, of course, the same labour could be utilised with a shorter working day. Looked at from this point of view, the problem of unemployment, tragic as it is to those concerned, takes on a less serious aspect from the point of view of the nation as a whole. It also shows to some extent the inevitability of the system of maintenance which is so unfairly described as "the dole." When all is said and done, industry is supporting both the employed and the unemployed, employed through wages, and the unemployed through taxation.

* * *

This is the reason why industry may some day wake up and demand the right to manage its own affairs in its own way, without handing over the administration of unemployment to the State.

* * *

Another argument arose out of a denial that spending on machinery and plant really meant saving. My friend agreed that spending on consumables was spending in the ordinary sense, but he could not agree that saving was any form of spending at all. It is, however, a very highly desirable form of spending except in the cases of that small minority of people which still prefers to save by putting money away in a stocking. The bulk of savings goes to the banks, insurance companies and building societies, and in all these cases only a proportion of the assets are retained in liquid form to meet immediate calls; the remainder is loaned, and usually provides credit facilities for industry, by which it is expended, not in consumable goods, but in plant and machinery for producing them.

* * *

However, I do not pretend that these views are either generally shared or that they are accurate, but I am prepared to defend them, largely because by so doing I should be a little more sure of my ground.

* * *

New Alphabet for Iron-founders.

G is for grumbling which never is heard,
Although comment kindly goes on undeterred.
H is for Heaven as well as for Hell,
Just choose where you'll go if you think you can tell.
I is for Iron, a word you mayn't use
Without proper trimming—cast—pig—what you choose.

Marksman.

Institute of Metals.

ABSTRACTS OF PAPERS.

"EIGHTH REPORT TO THE CORROSION RESEARCH COMMITTEE," by R. May, A.R.S.M.

The Report deals with some further investigations of "impingement attack" which were undertaken in order to interpret the results of certain tests on condenser tubes, and, in particular, to explain the relationship which appeared to exist between the effects of intermittent cavitation in the water, and the effects of air-bubble impingement.

Part I deals with the behaviour of protective films under various conditions of impingement. A method of studying this behaviour by measurements of the "film potential" is described in detail. The method is particularly useful for comparing the healing powers of the natural protective films on different condenser-tube alloys, and should be of assistance in the development of specially resistant condenser tubes.

Part II describes some experimental work which shows that, when there is no intermittent cavitation, "impingement attack" can still take place as a result of air-bubble impingement. This leads to the conclusion that there are two separate main causes of "impingement attack." In addition, the work shows that the size of the air-bubbles entangled in the water is a more important controlling factor than was formerly surmised. Very small bubbles seem to be comparatively harmless, even under conditions of strong impingement.

The investigation has been greatly assisted by the use of the jet-test apparatus, and this has developed into a form which is very convenient for preliminary tests on condenser tubes.

Part III is largely a discussion of the more important factors controlling "impingement attack" in condensers. The view is taken that there are two main causes—namely, intermittent cavitation as shown by Sir Charles Parsons, and air-bubble "impingement" as shown by Dr. Bengough, R. Pirret, and the author. In either case the mechanism of the action has points of great similarity, and both are known to depend to an important extent on the occurrence of rotating motions of the water.

Definite conclusions are reached regarding the prevention of "impingement attack."

"CORROSION AT DISCONTINUITIES IN METALLIC PROTECTIVE COATINGS," by Ulick R. Evans, M.A.

A study has been made of the corrosion occurring at different kinds of discontinuities in coatings of non-ferrous metals on steel; the work has included sprayed coatings of copper, nickel, and aluminium, and, in addition, coatings of zinc and zinc-iron alloy produced by hot-galvanising, electro-deposition, spraying, and sherardising. Various thicknesses of coating were employed, and the specimens were subjected to six different types of corrosion.

The cracks produced by bending are more dangerous than uniformly distributed pores. If the coating metal is cathodic to steel, the steel is corroded; copper under some conditions causes marked acceleration of the corrosion of steel at exposed places, nickel being less dangerous. If the coating metal is anodic to steel, the coating suffers corrosion preferentially, the steel thereby receiving protection; thus steel coated with zinc usually suffers no corrosion even at cracks until the zinc becomes exhausted. Steel thickly covered with zinc usually fares better than thinly-covered steel, notwithstanding the greater tendency to cracking; old galvanised sheet carried more zinc than the modern material, and generally lasted longer. Coatings of aluminium or zinc-iron alloys are themselves less attacked than coatings of free zinc, but for that very reason they afford less sacrificial protection to the underlying steel in certain waters. Zinc itself is rather rapidly attacked when partially immersed in a chloride solution, but alternate salt-spraying and drying was found to build up a protective film—a fact which explains certain observations made on the behaviour of galvanised iron in service.

"THE CONSTITUTION OF THE ALLOYS OF ALUMINIUM WITH COPPER, SILICON AND IRON," by A. G. C. Gwyer, B.Sc., Ph.D., H. W. L. Phillips, B.A., A.I.C., and Miss L. Mann.

After a brief summary of recent work on the binary alloys of aluminium with copper, silicon, and iron, the constitution and structure of part of the ternary systems aluminium-copper-silicon and aluminium-copper-iron are considered. The former of these is shown to be eutecti-ferrous, with a ternary eutectic of $CuAl_2$, aluminium and silicon, containing 26 per cent. of copper, 6.5 per cent. of silicon, and freezing at 525 deg. C. The aluminium-copper-iron system is shown to be rather more complex; a peritectic reaction occurs at 590 deg. C. between $FeAl_3$ and liquid resulting in the formation of a constituent isomorphous with "X"; the latter forms a ternary eutectic with $CuAl_2$ and aluminium, containing 32.5 per cent. of copper, 0.3 per cent. of iron, and freezing at 542 deg. C.

The structure and constitution of certain of the quaternary alloys of aluminium with copper, iron, and silicon are also considered. The constituents present, in addition to $CuAl_2$, are those of the aluminium-silicon-iron system, and a quaternary eutectic occurs at 26 per cent. copper, 6.5 per cent. silicon, 0.5 per cent. iron, freezing at 520 deg. C., the constituents being aluminium, $CuAl_2$, "X," and silicon. The Paper deals exclusively with metastable conditions.

"THE COPPER-MAGNESIUM ALLOYS," Part III, by W. R. D. Jones, M.Sc.

This Paper deals with notched-bar impact tests on forged and heat-treated copper-magnesium alloys. Further evidence has been obtained to show that there is no advantage in adding more than about 2 per cent. of copper to magnesium. Alloys containing more than 5 per cent. are brittle. The embrittling effect is decreased as the temperature rises. On exposure to cold, the toughness of these alloys has been decreased. Simple heat-treatment does not improve the notched-bar impact values to any appreciable extent.

The effect of forging on the microstructure has been to break down the eutectic network, resulting in an improvement of mechanical properties. Heat-treatment has merely increased slightly the size of the globules of Mg_2Cu and the crystal grains, which are rendered equiaxed and more regular in size.

"THE ROCKWELL HARDNESS TEST," by J. E. Mel[illegible]m.

The Paper describes work carried out in order to furnish data for conversion between (*a*) Rockwell and Brinell and (*b*) Rockwell and scleroscope numbers for copper, 95:5, 70:30 and 63:37 copper-zinc, and 80:20 cupro-nickel.

An examination of these data leads to the conclusion that the Rockwell ball test in its present form yields so-called "hardness numbers" which must be considered as quantitatively misleading. Similarly it is found that unscientific results are obtained owing to the arbitrary numbering of the scleroscope scale.

There is an increasing use of methods of testing which yield results having no rational quantitative significance. It is suggested that a representative committee be set up in order to consider the whole subject of hardness testing.

"PROPERTIES AND PRODUCTION OF ALUMINIUM DIE-CASTINGS," by S. L. Archbutt, F.I.C., J. D. Grogan, B.A., and J. W. Jenkin, Ph.D.

The Paper describes an investigation into (1) production and properties of aluminium alloy "die castings" made in permanent metal moulds under gravity feed, *i.e.*, without application of external pressure; (2) hot-shortness of aluminium die-casting alloys.

(1) Five alloys have been employed in the study of die-casting, namely, 4 per cent. Cu, 8 per cent. Cu, 12 per cent. Si, 4 per cent. Cu, 3 per cent. Si, and Y-alloy.

Two types of casting have been investigated: (*a*) A shouldered test-piece of circular section suitable for testing direct without machining; (*b*) a hollow tubular casting requiring use of cores in moulding, and incorporating flanges and changes of section, features which cause difficulties in casting. Design and treatment of moulds and conditions of working in respect to mould temperatures, pouring, stripping, etc., and the effect of the different alloy compositions on these are described, together with the testing and properties of the castings obtained. To overcome defects due to air locks, shrinkage, sticking of cores, etc., very careful control of the working conditions was necessary, including metal and mould temperatures, rate of pouring, interval between filling the mould and operations of drawing cores, opening the mould, and stripping.

By means of a practised team of workers these operations were carried out with the degree of accuracy needed, and considerable success was thus obtained. Satisfactory castings were produced in the tubular form from all the alloys studied. With the test-piece form castings of satisfactory mechanical strength were obtained in Y-alloy, 12 per cent. Si, and 3 per cent. Cu, 4 per cent. Si, but less satisfactory results were obtained with the binary copper-aluminium alloys owing to hot-shortness.

(2) In the investigation into hot-shortness the same five alloys have been studied together with L 5 alloy (Cu 2.5-3.0, Zn 12.5-14.0 per cent.). The energy absorbed in fracture of an unnotched test-bar cast to shape is taken as a measure of the hot-shortness. Some tests were made on freshly-cast bars as they cooled down, but the results mainly relate to bars re-heated to a steady temperature.

Hot-shortness is only exhibited at temperatures close to the temperature of commencement of melting. Within narrow temperature ranges the impact strength falls rapidly from the maximum striking energy of the machine to zero, or nearly so, at the commencement of melting. The range over which the rapid fall in impact strength takes place varies from 5 deg. C. with the 12 per cent. Si alloy to 45 deg. C with L 5.

"DIE-CASTING ALLOYS OF LOW MELTING POINT," by T. F. Russell, W. E. Goodrich, M.Met., W. Cross, B.Sc. and N. P. Allen, M.Met.

Sixteen zinc-base alloys, having either copper and tin, or copper and aluminium, and—in some cases—with further additions of either nickel, cadmium, lead or magnesium, have been examined microscopically and thermally, and their densities determined. Pressure-cast flat test-pieces were made of each of the alloys and examined for tensile strength, hardness, bending, and for porosity, with special reference to the influence of the casting temperature, the temperature of the mould, the size of gate and vent, and the type of pull on the lever of the machine. The porosity depends almost entirely on the kind of pull on the lever, but the differences due to the kind of pull become less as the gate is opened. The copper-aluminium-zinc alloys are approximately twice as strong as the copper-tin-zinc alloys. For any one alloy, the casting conditions—within reasonable limits—have only a small effect on the tensile strength when compared with the influence of the form of the test-piece, and of non-axial loading.

The effects on the strength and on the permanency of dimensions, after atmospheric ageing, have been investigated, and a very large number of tests of the so-called "accelerated ageing" type have been made. The "accelerated ageing" consists in subjecting the castings to the action of hot air, hot air saturated with moisture, and to steam at 100 deg. C. The general conclusions are set out, the most important one being that, within the limits of the compositions examined, the effect of the chemical composition on the rate of growth is insignificant when compared with the effect of the *form* and mechanical condition of the actual casting.

Work on the action of molten zinc and of zinc alloys on different ferrous materials was unfortunately left in an unfinished condition, and only the results of the action of molten zinc are given.

XUM

"THE X-PHASE BOUNDARY OF THE COPPER-SILICON SYSTEM," by Cyril Stanley Smith, D.Sc.

The x-phase boundary of the copper-silicon system has been redetermined by a series of annealing and quenching experiments. The solubility reaches its maximum value, 6.7 per cent. silicon, between 721 deg. and 782 deg. C. At 852 deg. C. —the temperature of the peritectic horizontal—the solubility is 5.25 per cent., while at 400 deg. C. it is only 4.1 per cent. silicon.

"THE STRENGTH OF A CADMIUM-ZINC AND OF A TIN-LEAD ALLOY SOLDER," by C. H. M. Jenkins, B.Sc.

A comparison has been made of the relative strengths in direct tension of a cadmium-zinc and a tin-lead solder under both rapid and prolonged tests, conducted at room temperature and at 120 deg. C. Marked differences between the strengths of cast, rolled, aged, and heat-treated material have been observed. Although a general similarity in type between the two materials was found, the cadmium-zinc alloy shows markedly higher values under the various tests. The tensile determined, is approximately four times that of strength of the cadmium-zinc alloy as ordinarily the tin-lead solder, but under prolonged stress tests the values obtained are approximately six times as great.

At 120 deg. C. both materials show a considerably diminished resistance to prolonged stress, the numerical values falling to somewhat below one-tenth of those observed at room temperatures.

"NOTE ON PRACTICAL PYROMETRY," by G. B. Brook, F.I.C., and H. J. Simcox, B.Sc.

The Paper outlines difficulties, such as stray current and magnetic fields of great intensity, which are peculiar to industries where large currents are used. An instrument has been designed which eliminates these, and is accurate even when placed in the field surrounding a conductor carrying as much as 20,000 amps. Various minor difficulties are dealt with, and a description is given of a quick-reading thermocouple which is suitable for use in non-ferrous foundries.

"WORK-SOFTENING OF EUTECTIC ALLOYS," by F. Hargreaves, A.R.S.M., and R. J. Hills.

Previous work is reviewed and the present state of knowledge on eutectics is briefly indicated. The micrographic changes on working and annealing the lead-tin eutectic are studied, and some explanation is offered of the existence of the critical amount of work observed at about 30 per cent. reduction. This corresponds to the same critical value previously found in ball hardness determinations.

A recrystallised sample of eutectic is found to soften when the amount of work exceeds about 20 per cent., and this shows that softening is not a peculiarity of the eutectic structure, but is due to the presence of two phases. The mechanism of distortion is discussed.

Experiments on 0.5 and 15 per cent. lead-tin alloys are described. The latter behaves very similarly to the eutectic, whilst the former may be rendered softer than the cast sample by working. The cadmium-zinc eutectic after preliminary working and annealing is found to behave very similarly to the cast eutectic on being worked again. It is considered highly probable that the phenomena investigated will be found to be operative during the hot forging of alloys containing more than one phase.

"METHODS FOR THE THERMAL AND MICROSCOPIC INVESTIGATION OF ALLOYS OF REACTIVE METALS," by William Hume-Rothery, M.A., Ph.D.

Methods suitable for the thermal and microscopical investigations of alloys of reactive metals are described and criticised, the subject-matter being arranged under the following headings:—(1) Methods in connection with cooling-curve experiments; (2) materials for crucibles and thermocouple sheaths; (3) methods for obtaining the true composition of the cooling-curve ingots at the moment of solidification; (4) the preparation of chill castings for annealing experiments; and (5) microscopic methods.

The Paper then discusses the justification for the method, introduced by the early German workers, in which the composition of a phase is deduced from the duration of the arrests of the cooling curves. It is shown that, whilst difficult to carry out, the method is sound in the case of simple eutectic arrests where no solid solutions are formed. But in the case of peritectic reactions, or where solid solutions are present, the method is by its very nature unsound at all except very high temperatures. The best methods for use where supercooling or suspended transformation are met with are then discussed.

"NOTE ON THE TREATMENT OF ALUMINIUM AND ALUMINIUM ALLOYS WITH CHLORINE," by D. R. Tullis.

Most aluminium alloys are known to contain dissolved gases. Various methods have been devised for their removal, and may be described as follows:—The slow solidification method, the inert gas method, and the active gas method. Various experiments are described in which chlorine gas is used as a means of removing dissolved gases. A theory is advanced to account for the presence of gases in metals. A comparison is given between the slow solidification and the chlorine methods. The results are shown by the difference obtained in the specific gravity before and after the various treatments. Further experiments describe the effects of chlorine gas on (*a*) alloys of aluminium which are known to extrude metal while cooling; and (*b*) alloys of aluminium which are known to disintegrate after long or short periods of storage.

Cohesibility of Rammed Sand.

Mr. Ivan Lamoureux writes as follows in reference to the discussion which took place upon his Paper bearing the above caption, and read before the Leicester meeting of the Institute of British Foundrymen.

He first wished to thank Mr. V. C. Faulkner for presenting the Paper, and felt extraordinarily flattered that such a modest contribution should give rise to so interesting a discussion. Primarily, the author neither mentally nor in his Paper has ever wished to stress any particular quality in Belgian sand. The observations related to sands in general. Thoroughly to understand all the peculiarities of moulding and to take into consideration all practical details encountered amongst foundry phenomena, the author, the son of a founder, worked as a moulder for a period of six years in various European countries and in America. He is however in a position to state, straightaway, that the sand used in New York State and in the Eastern part of Canada possesses qualities never met with elsewhere.

Microscopic Examination.

The author has microscopically examined moulding sands, but he has only used this study partially to control the observations that he has made in practice. Between the mould itself as made by a moulder and laboratory experiments there is a world unknown—irregularities, differences, surprises due largely to the fact that the foundryman and the scientist do not speak the same language, let alone understand each other.

The author has often seen the manner in which the samples for the laboratory are taken, and can say that without exaggeration that the laboratory is entirely at the mercy of the foundryman, who cannot realise the importance of certain precautions. The author is thus inclined to mistrust laboratory results, because chemists totally ignore the way in which the practical man has mixed his sands; the ramming and other moulding operations; quite often the moulders or foremen introduce some error—on purpose or by accident—when sampling.

The author recognises frankly that the diagrams are "imagination," but as Mr. Logan says, the diagrams are not to be taken too literally. Mr. Logan's micro-photographs are well known to the author, who perhaps some day will have at his disposal a laboratory which will allow him to present with exactitude and complete sincerity similar micrographic reproductions.

Patterns.

The phenomena associated with moulding from wood patterns are well known to every founder. The author does not ignore that the roughness of the wood can bring about surface defects in the vertical walls of the mould, but he insists that there is a difference in the structure of vertical walls even when they are made, using well polished metal patterns. Thus it is that he advances the hypothesis that the sand grains do roll over each other during ramming, and that they stop at a certain point of this rotation.

When ramming a flat surface the grain of the sand moves from the bottom to the top without being affected by rubbing against the pattern. This hypothesis is not very extravagant, and the diagram only serves to illustrate the explanation. It should be noted that Fig. 4 should be regarded from the vertical sense.

Runners.

It is sufficient to examine runners of square or polygonal section after sand blasting to satisfy oneself as to the numerous scabs they present. The author can only confirm this hypothesis, that is to say, that the ducts through which the mould gases and steam escape, progressively increase, as they become more distant from the metal, in a round runner, whereas in a square runner the section of these ducts remains constant. It has been definitely established that a cylindrical mould is always sounder than a cubical one.

Ramming Moulds in General.

In his own foundry before the war, the author, who frequently made moulds up to 25 tons, was able to study the difference between strickled and rammed moulds. It seemed to him that certain members had confused loam moulding with dry sand moulding.

Loam moulding ought not to be envisaged in this connection, because it is a branch of moulding quite different from that of sand moulding. Actually, with sand the sweeping board cuts the sand and tears the mass of the mould, whilst with loam the board carries the sand-mortar without tearing the surface at all. With sand the sweeping board turns with the bevel in front, whereas with loam the board turns with the bevel behind. For instance, in the case shown in Fig. 5 of the author's Paper, if one is sweeping sand one works the board to the left, whilst if it is a loam mould, the same board would be worked to the right. Thus the question of loam moulding does not enter into the discussion.

Conclusion.

One of the principal defects in iron castings in all countries is a scab characterised by an erosion of the mould which carries sand into the metal. The simple observations which the author has thought fit to make on this subject are such that they have convinced him that the serious defect known as scabbing can be remedied by a better understanding of the ramming of sand.

The author is happy in the knowledge that every speaker recognised that the subject was interesting, and that the study of it should be a matter for serious thought by all founders.

British Standard Automobile Parts.—The following new British Standards have been issued by the British Engineering Standards Association:—No. 5021—1928, British standard dimensions for unions, nipples and nuts (B.S.F. and B.S.P.) for automobiles; and Nos. 5037/8—1928, British standard dimensions for centres for artillery wheels, centres for steel disc wheels, hub flanges for steel disc wheels, for automobiles. Copies of the above may be obtained from the Publications Department, B.E.S.A., 28, Victoria Street, Westminster, S.W.1. Price 2s. 2d. each, post free.

Safety First Conference.—Altogether 45 countries were represented at the recent International Safety-First Conference at Geneva, each country, as a rule, sending four delegates—two representing the Government and one apiece the workers and the employers—together with a number of technical advisers. A full report is published in "Safety First," the official organ of the National Safety First Association. At its closing sitting the Conference formally decided by a unanimous vote to place the following two items on the agenda of the 1929 Session:—(1) The prevention of industrial accidents; and (2) the protection against accidents of workers employed in loading or unloading ships.

Laboratory Experiments on High-Temperature Resistance Alloys.*

By C. J. Smithells, D.Sc., S. V. Williams, B.Sc., and J. W. Avery, B.Sc.

Introduction.

Although for many years the alloys of nickel and chromium have been in general use where resistance to oxidation at high temperatures is required, the published data concerning them are very meagre. So far as the authors are aware, the equilibrium diagram does not appear to have been accurately determined. According to Voss, [1] the metals form a continuous series of solid solutions, a minimum in the freezing-point curve occurring at 1,280 deg. C. with 42 per cent. of chromium. The crystal structure of the whole series from pure nickel to pure chromium has been investigated by Balke, Lord, and Focke.[2] The microstructure of these alloys, as affected by composition, heat-treatment, etc., does not appear to have been studied. Certain physical properties, such as resistivity and temperature coefficient of resistance, of commercial brands of nickel-chromium alloys have been measured, and this information is supplied by the manufacturers, and has been summarised in several Papers.[3] In many cases, however, the exact composition of the alloys is not stated, and the data refer only to the alloys containing 15-30 per cent. of chromium.

The resistance to oxidation, which is one of the most valuable properties of these alloys, is difficult to measure, and it is generally impossible to compare the results obtained by different workers using different methods of testing. The most systematic work in this field is that of Rohn,[4] who compared the oxidation resistance of nickel-chromium alloys containing 11, 15, and 20 per cent. of chromium, and nickel-chromium-iron alloys containing from 15 to 33 per cent. of chromium. Rohn's method of testing gives results which are not directly comparable with conditions of service in which these alloys are used.

The nickel-chromium alloys are mainly used for three types of service:—(1) As castings for moulds, boxes, etc. (2) As rod or sheet for constructional purposes, furnace parts, etc. (3) As wire or strip for resistors in electrical heating apparatus.

The authors were mainly interested in the third of these applications, and this Paper gives an account of a preliminary survey of this field. The primary object of the work was to devise tests which would give definite information as to the relative merits of different alloys in the form of wire for use in electrical heating apparatus. This involved an investigation of the various factors which may lead to failure in service. In order to study these factors more fully a number of nickel-chromium alloys of different compositions, as well as a few ternary alloys, were prepared. These alloys, together with representative commercial alloys, were subjected to the proposed tests, and also tested in service in various domestic heating appliances. The effect of composition on the following properties of the alloys has been investigated:—(1) Resistance to oxidation at high temperatures; (2) electrical resistivity and temperature coefficient of resistance; and (3) resistance to sag or creep at high temperatures.

In addition, a certain amount of information has been obtained about the mechanism of oxidation of these alloys, and the effect of impurities on their properties. The results obtained are necessarily incomplete, but indicate certain directions in which further research might usefully be made.

Preparation of Alloys.

Commercial nickel-chromium alloys nearly all contain 15 or 20 per cent. of chromium, but, as there was no evidence that such alloys were the most suitable, it was decided to make as complete a range as could be worked. It seemed desirable to make these alloys as pure as possible without regard to the possibility of reproducing them on a larger scale. Melts of 12 to 200 grm. were made from specially purified materials, melting being carried out in an atmosphere of hydrogen to prevent oxidation.

Melting Process.

Bars were pressed and placed in special refractory boats, made either from magnesia or sillimanite. A silica tube, through which a stream of pure hydrogen passed, was placed in an alundum tube furnace giving temperatures up to 1,600 deg. C., and the boat carrying the bar introduced into the hot zone. Nickel melts at 1,452 deg. C., and chromium at about 1,550 deg. C., the latter temperature being sufficient to cause complete fusion of any alloy of the series. After the metal had melted it was held in the molten state for 5-10 minutes, and the boat then pushed into the water-cooled end of the tube. Some difficulty was experienced at first in obtaining ingots free from blowholes, and it was finally found most satisfactory to remelt the ingots, by which means completely sound metal was regularly obtained. A series of 12-grm. ingots was prepared by this method, the compositions of which are given in Table I. No analyses of the alloys were made after melting, since by this method of preparation there was no loss of metal and no oxidation, the surface of the ingot being quite bright. Spectroscopic analysis showed that a small amount of silicon is taken up by nickel when melted in a sillimanite mould, but there is no contamination by magnesium when magnesia is used. Alloys up to and including No. 26 were made with reduced nickel. When preliminary tests had indicated which were the most likely to be useful, repeat batches were made with electrolytic nickel, and a comparison of their properties has shown that the effect of the comparatively small difference in purity is important.

TABLE I.—*Composition of Alloys.*

	Alloy No.	Cr	Ni	W	Mo
		Per cent.	Per cent.	Per cent.	Per cent.
Reduced nickel	9	10	90	—	—
	10	20	80	—	—
	11	30	70	—	—
	12	40	60	—	—
	14	50	50	—	—
	15	60	40	—	—
	16	10	85	5	—
	17	10	80	10	—
	18	10	70	20	—
	19	20	75	5	—
	20	20	70	10	—
	21	10	85	—	5
	22	10	80	—	10
	23	10	70	—	20
	24	20	75	—	5
	26	20	70	—	10
Electrolytic nickel	27 (10)	20	80	—	—
	30 (9)	10	90	—	—
	31 (11)	30	70	—	—
	32 (19)	20	75	5	—
	33 (26)	20	70	—	10
	34 (24)	20	75	—	5

Mechanical Working.

The alloys containing up to 40 per cent. of chromium, and all those containing tungsten or molybdenum, were remarkably ductile and could be cold-rolled with ease, but work-hardening became considerable after about five passes. They were therefore alternately reduced 20 to 30 per cent. in diameter by rolling, and annealed for 10 minutes in hydrogen at 1,200 to 1,300 deg. C. down to 2 mm. dia. From 2 mm. to 0.8 mm. dia. reduction was effected by swaging, the wires being annealed at 1,000 deg. C. in air as required, by drawing through a tube furnace. The final reduction to a standard diameter of 0.375 mm. was by drawing cold through diamond dies, lubricated with tallow. The wires were annealed once during drawing and again after the last die.

The first alloy to give trouble in working was No. 14. This alloy was very hard and could only just be drawn. No. 15 was glass hard and could not be worked either hot or cold.

MICROSTRUCTURE.

The structure and constitution of the alloys have not been thoroughly investigated, but from a preliminary examination of a few specimens certain general conclusions can be drawn.

Nickel-Chromium Alloys.

In the worked and annealed state the alloys containing up to 40 per cent. of chromium consist of a simple solid solution showing a polygonal structure with frequent twins. For the same treatment the grain-size shows a steady decrease with increasing chromium content. The 50 per cent. chromium alloy contains two distinct phases, and shows a greatly increased hardness; whilst the 60 per cent. chromium alloy is hard and brittle. It is evident that the nickel-chromium alloys do not form a continuous series of simple solid solutions as indicated in Voss's equilibrium diagram. The alloys containing more than 60 per cent. of chromium have not yet been investigated.

Nickel-Chromium-Tungsten Alloys.

The rolled and annealed alloys containing from 0 to 20 per cent. of tungsten with 10 per cent. of chromium, or from 0 to 10 per cent. of tungsten with 20 per cent. of chromium, all have the twinned structure typical of the nickel-chromium alloys.

Nickel-Chromium-Molybdenum Alloys.

These alloys correspond to the tungsten alloys of similar composition, except that the 20 per cent. Mo, 10 per cent. Cr alloy shows a second phase in the grain boundaries, which appears as a eutectic in the cast alloy. Both series of ternary alloys show the same decrease in grain-size with decreasing nickel content as was observed in the binary alloys.

In general, therefore, the alloys containing up to 40 per cent. of chromium, and the series of alloys containing small amounts of tungsten and molybdenum, all belong to the same type of simple solid solution. The higher chromium alloys, and probably higher alloys of the other series, have 2 phases. The appearance of the second phase in the binary alloys produces a sudden change in properties, which, as will be shown, renders them unsuitable for heating wires. It is still possible that alloys at the other end of the system—that is, mainly chromium with additions of nickel, etc.—might be suitable.

RESISTANCE TO OXIDATION.

Electrical Resistance Method.

Two methods have been in use for determining the relative resistance to oxidation of different nickel-chromium alloys. The first consists in measuring the change in electrical resistance of a sample of wire after various periods of heating at a definite temperature in air. This assumes that the change in electrical resistance is due entirely to oxidation, and consequent reduction in the effective diameter of the wire. The electrical resistance of nickel-chromium alloy wires is considerably affected by variations in mechanical and thermal treatment. For this reason the method is not very satisfactory.

Weight Increment Method.

The second method consists in measuring the increase in weight due to oxidation when a sample of wire is maintained at a constant temperature in moist air or oxygen for various periods of time. A large number of alloys were tested in this way. The relative order of merit given by these tests was found to be quite at variance with the result of practical tests in heating appliances,

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* Extracted from a Paper read before the Liverpool Meeting of the Institute of Metals. The authors are members of the Staff of the Research Laboratories of the General Electric Co., Ltd., Wembley.

[1] "Z. anorg. Chem.," 1908, 57, 60.

[2] "Phys. Rev.," 1927, 29, 206.

[3] Merica, "Chem. and Met. Eng.," 1921, 24, 651; "Amer. Soc. Test. Mat.," 1924, 24, 189.

[4] "Elektrotech. Zeit.," 1927, 48, 227 and 317.

and with the results of a later form of test described in the next section. Certain alloys showed a decrease in weight during the test, although considerable oxidation had taken place. When a cooled silica U-tube was attached to the end of the furnace tube a brown deposit of sodium chromate was obtained. A similar effect is observed if a wire is heated in a glass bulb having a side tube open to the air. This deposit was obtained from all alloys except those made from the purest materials, and was most marked with the commercial nickel-chromium alloys. The loss in weight from this cause may be comparable with the increase in weight due to oxidation, and the results are therefore unreliable.

Life Test Method.

Form of Test Wire.—The following method of test was finally adopted to obtain a rapid indication of the relative value of different alloys for use as heating elements. The wire is wound as a short helix and attached to the nickel leading-in wires of a lamp seal capable of carrying 10 amp. The junction with the nickel leading-in wires is made by pinching the end of the test-wire in the bent end of the nickel leads, leaving about $\frac{1}{8}$ in. of the test-wire extending outside. This is then run up to the nickel wire by means of an arc in forming gas,* to ensure perfect electrical contact. Such specimens require 8-9 v. to

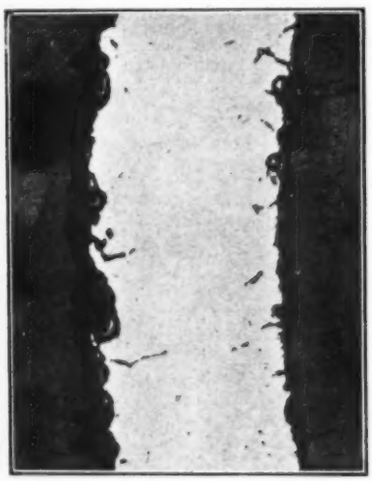


Fig. 1.—Alloy showing protective type of Oxide layer unetched × 100.

operate at 900 to 1,000 deg. C. To protect them from draughts they were at first enclosed in glass bulbs having an opening to the air, but it was found that the deposit of sodium chromate already mentioned interfered with subsequent temperature measurements. Comparative tests showed that for wires larger than 0.375 mm. in dia. the effect of draughts was negligible, the same test life being obtained when no bulbs were used. Tests were therefore carried out with the wires mounted in the open and burning horizontally.

Temperature Measurement.—The temperature of the specimens was measured by means of a special colour-matching photometer, in which the colour of the light from the specimen was matched in a Lummer-Brodhun photometer head against the colour of a standard carbon-filament lamp calibrated against a black-body furnace. The standard lamp having been set to the desired colour temperature, the volts across the test specimen were adjusted until a match was obtained. The specimen was then set up on test at this voltage. A similar procedure was followed in determining the temperature of the specimen at any period during the test, the specimen being set up at its test voltage and the standard lamp being adjusted to obtain a colour match. This method gives the average colour temperature of the wire, and provided the temperature is uniform over the whole length, this temperature is very near to the true temperature. Readings could be repeated within ± 10 deg. C. at 1,000 deg. C.

Ageing.—If the voltage across the test-wire was kept constant, it was found that a considerable fall in temperature occurred during the first few hours with many alloys. All specimens were therefore aged for 4 hrs. at 1,100 deg. C. before being set up on test.

Continuous and Intermittent Tests.

There was some evidence that with all electrical heating appliances the life is shorter on intermittent than on continuous tests. Wires were

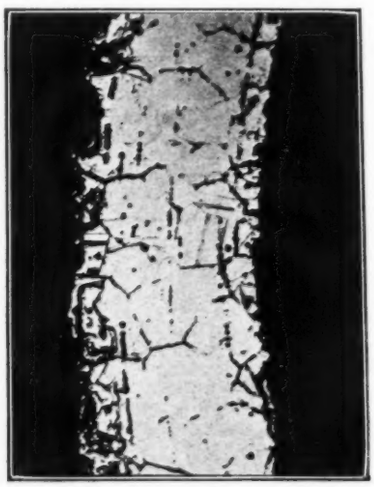


Fig. 2.—Same specimen as Fig. 1 etched with Cully & Aqua regia × 100.

therefore tested under both conditions. In the "Continuous Test" the current was switched off for $\frac{1}{2}$ hr. every 12 hrs. For the "Intermittent Test" an automatic contact breaker was incorporated in the heating circuit by which the current was switched on and off every 2 minutes.

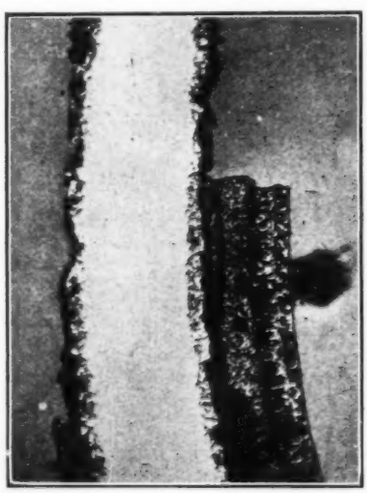


Fig. 3.—Alloy showing non-protective type of oxide layer unetched × 100.

This method of test was extended to determine the effect of heat-treatment, wire diameter, pitch of spiral, and different periods of intermittency on the life of wires at different temperatures.

Discussion of Results.

In comparing the lives obtained with different alloys, it is necessary to take into consideration the fact that the initial temperature is not maintained throughout life. Whilst the temperature of some wires may fall only 10 or 20 deg. C. during a period of 500 hrs., in other cases it may fall 100 deg. C. in 100 hrs. In the latter case the average temperature of the wire during test is lower, and the life longer, than if the initial temperature had been more nearly maintained. Wires which show a large change in temperature during life are unsuitable for use in heating appliances. Decrease in temperature may result either from increased resistance due to oxidation, or from sagging and distortion of the coil, which leads to excessive loss of heat by conduction and convection in the surrounding air. Alloys which showed a fall in temperature exceeding 100 deg. C. during life were therefore neglected in assigning an order of merit.

Alloys 9, 10, and 11 show a steady increase in life with increase in chromium content up to 30 per cent., but the life is shorter again with 40 per cent. of chromium (alloy 12). The 50 per cent. alloy was not tested, since it showed excessive sagging, probably connected with the presence of the second phase. The inferiority of the 40 per cent. alloy may also be due to this cause.

The influence of impurities on the life of these alloys is seen by comparing the test results for alloys 9, 10, and 11 made with reduced nickel, with those for alloys 30, 27, and 31 of similar composition made with electrolytic nickel. In spite of the small difference in the purity of the nickel, it will be seen that a consistently longer life is obtained for the purer alloys in each case. The

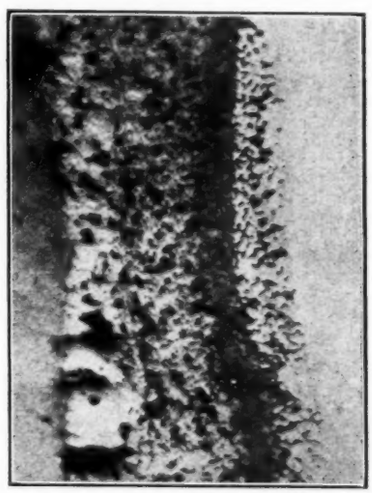


Fig. 4.—Similar specimen to Fig. 3 × 500. (The unchanged metal is on the right.)

commercial alloys *A* to *D* have the same nominal compositions as alloy 10, but give still shorter lives, presumably due to the higher percentage of impurity present.

The results for the ternary alloys are of interest, and emphasise the importance of small changes in composition. The alloys containing 10 per cent. of chromium with 5, 10, or 20 per cent. of either tungsten or molybdenum (alloys 16 to 18, and 21 to 23) gave lives which were actually shorter than for the binary alloy containing the same amount of chromium. With 20 per cent. of chromium and 5 or 10 per cent. of either tungsten or molybdenum (alloys 19, 20, 24, and 26), the lives were comparable with those of the best binary alloys. It therefore appears that to obtain a satisfactory ternary alloy there is a minimum percentage of chromium which must be present no matter what other additions are made.

The frequent heating and cooling of the wire greatly reduces the life. This is due to the protective oxide layer becoming detached from the wire as a result of differential thermal expansion. For the majority of the alloys tested the life on intermittent test is less than one-tenth of the life on continuous test, but for alloys 31 and 33 the difference is less marked. This indicates that the oxide layer is more adherent, and alloy 33 appears to be definitely the best of those tested.

* A mixture of 80 per cent. of nitrogen and 20 per cent. of hydrogen.

This conclusion has been supported by a number of tests in domestic heating appliances.

Mechanism of Oxidation.

Both nickel and chromium, and all their alloys, are readily oxidised, but their success as heating elements depends upon the protective nature of the oxide film formed on their surface. The nature of this film and the way it is affected by the composition of the alloy has been investigated, since a knowledge of the phenomena concerned is fundamental to the development of the most suitable alloy.

Types of Oxidation.

Microscopic examination of sections of wires which had been on life test showed that at least two types of oxidation occurred with the different alloys, and that the alloys could be divided into two classes on this basis. It was further found that this classification was in complete agreement with the results of life tests, and showed a definite relation to the composition of the alloys.

Composition of Oxides.

X-ray analysis has been used to determine the nature of the different oxides formed. The authors are indebted to Mr. H. P. Rooksby for taking the X-ray photographs and for his co-operation in this section of the work. Three oxides may be formed on the surface of a nickel-chromium alloy—chromic oxide (Cr_2O_3), nickel oxide (NiO), and a compound of the two, nickel chromite ($NiO.Cr_2O_3$). These oxides are present in the surface of nearly all wires, but in very different proportions. The nickel chromite represents only a small proportion, and may probably be neglected. The protective type of oxide contains a larger proportion of chromic oxide than the non-protective oxide. Analysis of the oxide scale which falls from a wire during life shows that this is mainly nickel oxide. The oxide formed by the tungsten alloys contains an unknown compound, the proportion of which increases with the tungsten content. This is probably a compound of tungsten and nickel.

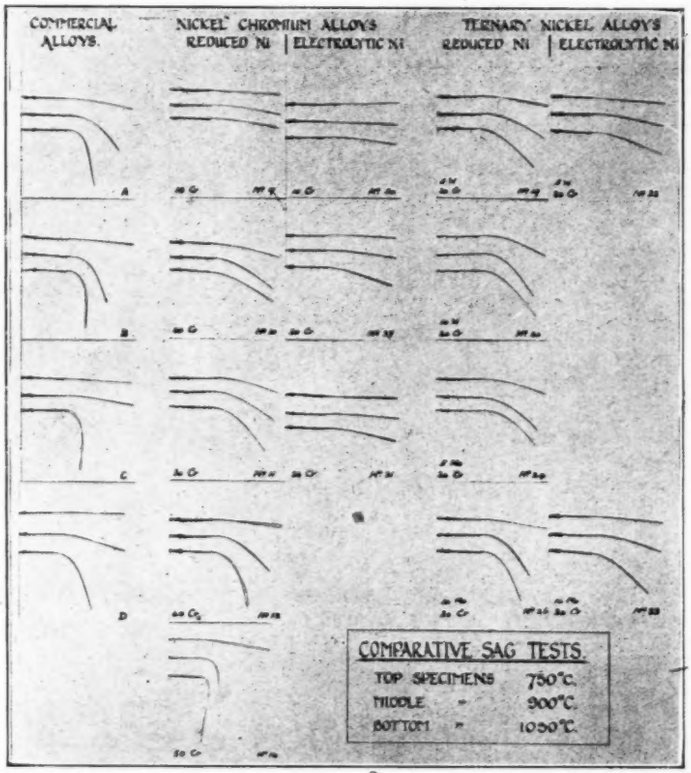


FIG. 5.—COMPARATIVE SAG TESTS.

In the first type, which may be looked upon as the desirable one, a very thin adherent film forms on the surface of the wire. Once formed it increases in thickness only very slowly. At a later stage the oxide begins to penetrate the grain boundaries, and in course of time extends across the wire. The increased resistance produced raises the temperature locally, and finally fusion takes place. Fig. 1 shows an unetched section of a wire with a surface film of uneven thickness and grain boundary penetration just beginning. Fig. 2 shows the same section etched, which develops the grain boundaries and makes the nature of the penetration clearer.

In the second type the superficial layer of oxide, although it may be fairly adherent, appears to offer very little resistance to the diffusion of oxygen. The film increases rapidly in thickness until eventually the whole wire is converted into oxide. Fig. 3 shows an early stage in the process, the oxide having been broken off the surface of half the specimen. Fig. 4 shows the nature of the oxidation at higher magnification. In this type the general temperature of the wire falls rapidly, but oxidation still proceeds, owing to the lack of a sufficiently protective film.

In Table II are given the results of X-ray analysis of the oxides formed on the surface of the different alloys after being heated to 1,000 deg. C. in moist oxygen for 10 hrs. The percentage composition is estimated to the nearest 10 per cent. from the relative intensity of the lines in the X-ray spectrum. The lives on continuous test at 1,100 deg. C., and the nature of the oxidation as seen under the microscope, are included for comparison.

It will be seen that the composition of the oxide layer is determined by the composition of the alloy, but is not in general the same as that of the alloy. In the binary alloys the proportion of chromic oxide in the layer increases rapidly with increase in chromium content in the alloy. All these alloys develop the thin protective type of oxide, but grain boundary penetration is more rapid in those of low chromium content. The ternary alloys containing 10 per cent. of chromium develop an oxide layer containing very little chromic oxide. This layer is of the non-protective type, and accounts for the very short lives obtained with these alloys. The ternary alloys with 20 per cent. of chromium develop a protective oxide containing more than 50 per cent. of chromic oxide, and their lives are comparable with those of the binary alloys forming similar oxides. The formation of the tungsten compound, which is well marked in the alloys containing only 10 per cent. of chromium, does not occur in the alloys containing 20 per cent. of chromium.

TABLE II.—*Analysis of Oxides formed on Nickel-Chromium Alloys.*

Alloy No.	Life on continuous Test at 1,100° C. Hrs.	Type of oxidation.	Approx. % Composition.		
			Cr_2O_3.	NiO.	Tungsten Compound
9	120	Protective	10	90	—
10	670		80	20	—
11	720		> 90	< 10	—
12	230		> 90	< 10	—
16	27	Non-protective	20	70	10
17	44		20	55	25
18	35		0	50	50
19	403	Protective	70	30	—
20	633		50	50	—
21	13	Non-protective	10	90	—
22	45		10	90	—
23	45		10	90	—
24	283	Protective	90	10	—
26	540		90	10	—

From these results the general conclusion may be drawn that for satisfactory oxidation resistance the composition of the alloy must be such that the oxide formed contains at least 50 per cent. of chromic oxide. Higher proportions of chromic oxide do not necessarily confer greater powers of resistance.

Resistance to Sag.

In certain types of heating appliances the wire is only supported at intervals, and it is desirable that it should not distort or sag under its own weight during life. In the usual methods of determining creep stress much larger loads are generally applied, but it is probable that a high creep stress would correspond to a high resistance to sag. A similar problem is encountered in the manufacture of non-sag tungsten filaments for incandescent lamps, and a test commonly employed in this connection has been adopted for testing nickel-chromium alloys, owing to the rapidity with which it can be carried out.

The test-wire, 0.375 mm. in diameter, is bent into the form of a hairpin. The ends of the wire are joined to the nickel lead-in wires of an ordinary lamp seal by spot-welding. Four such hairpins are mounted horizontally and raised by suitable currents to temperatures of 1,050, 900, 850, and 750 deg. C. respectively. After 1 hr. the current is switched off, and the angle which the line joining the tip of the hairpin to the spot-weld makes with the horizontal is measured. For each alloy it is then possible to record the temperature at which the angle of sag equals some arbitrary value, say 15 deg.

For purposes of a more direct comparison specimens tested at 1,050, 900, and 750 deg. C. respectively were photographed for each alloy. These photographs are reproduced in Fig. 5. The results of repeat tests on the same alloy were found to be in good agreement.

It will be seen from Fig. 5 that the resistance to sag of the binary alloys decreases steadily with increasing chromium content. The 50 per cent. chromium alloy sags more or less completely at 1,050 deg. and 900 deg. C., whereas it is practically non-sag at 750 deg. C., which seems to indicate that the second phase, already noted, is particularly weak at the higher temperatures.

The presence of impurities has a marked effect on the resistance to sag, alloys 9, 10 and 11 showing considerably more sag than the corresponding alloys 30, 27 and 31 made from electrolytic nickel. In the same way the commercial alloys *A* to *D* show more sag, particularly at high temperatures, than alloy 10, which has the same chromium content.

The ternary alloys containing 20 per cent. of chromium sag slightly more than the binary alloys having the same nickel content. The influence of impurities is again emphasised by comparing the

results for alloys 19 and 26 with those for alloys 32 and 33 made from electrolytic nickel.

Whilst this test is very severe it affords a quick and easy method of comparing the relative resistance to sag of different alloys. The order of merit assigned in this way has been found to be in agreement with that obtained from examination of the life test coils after 500 hrs. test.

ELECTRICAL RESISTIVITY.

Experimental.

The electrical resistivities of many of the alloys have been determined over a temperature range between room temperature and 1,000 deg. C. The authors were chiefly concerned with the shapes of the resistivity-temperature curves rather than with absolute values, which are probably not more accurate than ± 2 per cent. The resistivity was calculated from observations of the potential difference between two points on a specimen of known dimensions, when carrying a measured small current. The specimen was in the form of a hairpin, with current and potential leads, and mounted in a transparent silica tube, through which a slow stream of commercial nitrogen was passed, which prevented appreciable oxidation of the alloy. The whole was heated in an electric tube furnace. The temperature was determined by means of a Hoskin's chromel-alumel thermocouple, mounted adjacent to the specimen. Wire, uncleaned, as drawn, and of a standard diameter of 0.375 mm., was used; and the specimens had resistances between 1 and 2 ohms. Observations were made, at steady temperatures, at intervals of 50 deg. or 100 deg. C., during heating and cooling. A complete cycle occupied about 3 hrs. The readings taken during cooling in the second cycle were normally used for the final calculations.

Discussion of Results.

The values obtained during the first heating are lower up to 500 deg. C. than those obtained during subsequent cycles, which were found to be in close agreement with one another. This may be due to the incomplete annealing of the specimen as mounted, since, according to Rohn,* the resistance of nickel-chromium alloys is lower in the cold-worked than in the annealed condition. This is in agreement with the fact that if the specimen was removed from the tube after a complete cycle, and deformed a little with the fingers, lower values were obtained during the first part of the heating half of the next cycle.

Electrical resistivity-temperature curves for a number of the binary and ternary alloys are similar in shape, and show a maximum, or an inflection, between 500 and 550 deg. C. Alloy 14 (50 per cent. Ni, 50 per cent. Cr), which has been shown to be of a different type from the others investigated, has, comparatively, a very large positive temperature coefficient of resistance.

In general, the resistivity at room temperature increases as the nickel content decreases. Substitution of part of the chromium by tungsten lowers the resistivity; whilst similar substitution by molybdenum raises it. The molybdenum alloys, therefore, have higher resistivities than the corresponding tungsten alloys.

The temperature coefficient of resistance is less for the alloys of higher resistivity, and, in most cases, becomes negative above about 600 deg. C.

Alloys 23 and 26 have a slightly lower resistivity at 1,000 deg. C. than at room temperature; whilst alloys 19, 20, 22 and 24 show practically no difference between their respective resistivities at these two temperatures.

* "Elektrotech. Zeit.," 1927, 48, 227.

An Industrial Battery Locomotive.

It is somewhat surprising that the possibilities of the battery locomotive for duties on the sidings in connection with collieries and iron and steelworks have hitherto received so little consideration, though for many of the duties in connection with the sidings the electric locomotive would surely prove an economical proposition. On an average the works locomotive is "standing by" for at least 25 per cent. of the working day, frequently very much more; the head of steam, however, has of course to be maintained, whereas the battery locomotive is only consuming energy when actually performing work.

It is quite true that some few battery locomotives are engaged upon the duties referred to, but hitherto these appear to have been built somewhat on the light side, and consequently have not always proved equal to dealing with the loads imposed upon them, with the result that the motive power has been blamed, whereas the fault lay with the weakness in the method of its application. Obviously to convert the power of the motor or motors into tractive energy, there must be sufficient weight to enable the wheels to hold the track, and insufficient attention to this important detail has in some cases been responsible for unsatisfactory working.

Another error has been to give too high a rated speed of travel, which has resulted in cutting down the draw-bar pull. On the works sidings it is generally impossible to make use of a high speed of travel; 1,000 lbs. on the draw-bar pull is of infinitely greater moment than an additional mile an hour in the speed.

The electric locomotive which we illustrate has been built by the Sanderson Bibby Company, Limited, Victoria Street, London, S.W.1, particularly for works duty. Its overall length is 24 ft.; width, 8 ft.; height from top of rail to top of cab, 10 ft. 6 in.; wheel-base, 8 ft.; whilst the total weight, depending to some extent upon the capacity and make of the battery, is approximately 22½ tons. The locomotive is capable of exerting a draw-bar pull of 8,000 lbs., and travelling at a speed of 4/4½ miles per hour. The travelling speed, however, is considerably greater with lighter loads.

The locomotive is equipped with two motors of the "Goodman" railway type, each one-hour rated at 75 h.p. normal on 250 volts. Special consideration having been given to the windings enables these motors to operate at high efficiency on lower battery voltages.

All running and wearing parts are generously proportioned. The combination of a structural steel frame, coil springs and three-point motor suspension makes a flexible unit capable of following an uneven track easily. It also allows of a longer wheel-base on short curves without strain, and gives high tractive effort per ton of weight. All parts are easily accessible. The motors are swung outside the axles, enabling the armatures to be removed from the top when the battery boxes are lifted. The battery boxes are instantly removable without disturbing the mounting of battery trays or individual cells. They are fitted with patent swinging covers requiring only one man for their operation. These boxes are capable of receiving a battery of capacity equivalent to approximately 1,200 ton-miles per charge, on level track with a train resistance of 25 lbs. per ton.

In addition to a very efficient hand brake, which acts on all wheels, the locomotive is equipped with air brakes of the Westinghouse Brake and Saxby Signal Company, Limited, manufacture. The whole of the control apparatus is conveniently located in the central cab, which is fitted with glass windows, giving the driver a clear view when travelling in either direction.

Fig. 1.—General View.

Fig. 2.—Hauling Train.

Industrial Battery Locomotive by Sanderson Bibby Company, Limited.

A meeting of the creditors of Messrs. Joshua Buckton & Company, Limited, engineers and tool makers, Meadow Lane, Leeds, in voluntary liquidation, was held on Monday in Leeds, Mr. Alex. Kennedy, the liquidator, presiding. From a statement of affairs put into the hands of those present, it appeared that the liabilities included £8,106 owing to unsecured creditors and £77,614 to creditors partly secured, £73,168 being secured on all the assets by an issue of debentures dated December, 1920. The company had fully-paid-up capital of £150,000, and the deficiency as regards contributories was £162,552, and as regards creditors £12,552. The chairman said that early this year the directors came to the conclusion that the best course for all concerned was for the company to combine with some stronger firm, and in March last they entered into arrangements with Messrs. Craven Brothers (Manchester), Limited. The agreement provided for the sale of the goodwill, patterns, etc., for £12,000, and for the sale of certain plant for £12,500—both sums being payable in shares. Messrs. Craven Brothers had contracted to buy the stock-in-trade and the work in progress. No resolution was put to the meeting, and it is understood that the company's affairs will be left in the hands of the liquidator.

Note on the Treatment of Aluminium and Aluminium Alloys with Chlorine.*

By D. R. Tullis.†

The Removal of Dissolved Gases from Aluminium and its Alloys.

It is now an established fact that aluminium and its alloys contain considerable quantities of dissolved gases. In pure aluminium the gases are generally in complete solution, and when liberated may be equal to about one-third of its volume. In aluminium alloys the gases are not always in complete solution, and during solidification make their presence known in the form of blowholes and gas cavities. This fact explains many of the troubles encountered in the casting of aluminium and its alloys. Gases also exist in a combined form, such as the nitride and oxide of aluminium. Carbon also is present in the form of carbide of aluminium. In aluminium, Gwyer‡ states that of the various gases given off, hydrogen is the predominant gas in the metal. On heating the metal *in vacuo*, it has been found that hydrogen equals 50-80 per cent., nitrogen 5-11 per cent., carbon dioxide 4-8 per cent., carbon-monoxide up to 7.5 per cent., acetylene up to 25 per cent., oxygen 1.5-4.5 per cent. Czochralski§ states that aluminium begins to dissolve gases in appreciable amount only above 900 deg. C. He also states that nitrogen is least soluble, and that the solubilities of gases increase in the following order, CO, O, SO_2, CO_2, H. Nitrogen is partly dissolved as aluminium nitride. Carbon monoxide and carbon dioxide closely resemble each other in their effects and form aluminium carbide. Hydrogen is readily soluble.

The Disturber Element Theory.

In order to bring about effective degasification of aluminium and its alloys, it is assumed that it is necessary to introduce an element which upsets the equilibrium existing between the aluminium and the dissolved gases. This element could be called a "disturber" element, and may be a metal or a non-metal. In the case of aluminium alloys, it has been noted that the addition of small quantities of magnesium causes the appearance of marked unsoundness. For this reason magnesium is considered a "disturber" element. For the same reason the element zinc may be termed a "disturber" element.

Removal of Dissolved Gases.

In this research, an attempt was made to remove all or part of the dissolved gases in aluminium and its alloys (which contain dissolved gases). In many cases the gases are not apparent, as they remain in solution during foundry melting. In other cases, due to the addition of certain elements, the dissolved gases make themselves more apparent. When this occurs, many casting troubles manifest themselves in the form of pinholing, gas cavities, porosity, and low density; in consequence, certain methods of improvement have been devised. The chief of these is that due to S. L. Archbutt. This method expels some of the dissolved gases in the melt. It consists of slowly solidifying the alloy in the crucible in which it is melted. When the metal has just completely solidified, it is remelted quickly and cast in such a manner that the possibility of reabsorption of appreciable quantities of harmful gases is small. Archbutt has also carried out some experiments by passing dry nitrogen gas through "Y" alloy, which had already been slowly solidified. The extra gain in specific gravity was about 0.35 per cent., a very small amount. Below is given an extract from his Paper entitled "A Method of Improving the Properties of Aluminium Alloy Castings."¶

	Density.			Elongation. Per cent.
	Sand-Cast Bars.	Unmachined	Machined	
Minimum ..	2.720	2.730	2.741	0.5
Maximum ..	2.780	2.785	2.783	1.5
Gain ..	0.06	0.055	0.042	—

Simple Remelting.—Minimum sp. gr. 2.720, normal sand-cast; maximum sp. gr., 2,747, ingotted and remelted; and gain in sp. gr., 0.027 = 0.99 per cent.

Maximum Gain by Slow Solidification Method (0.061 = 2.33 per cent.).—Slow solidification and nitrogen gassed, 2.795; maximum of slow solidification only, 2.785; and gain by gassing, 0.01 = 0.35 per cent.

In the first place, it is necessary to find out which element causes the greatest disturbance to the equilibrium existing between the aluminium and its dissolved gases. In "Y" alloy, and also in many similar alloys, it is assumed that the magnesium is the "disturber" element. Most alloys containing magnesium are very prone to develop unsoundness when sand-cast. The author attempted to find an element which would cause a greater disturbance than magnesium. As a basis he used alloys of aluminium and zinc. When a basic alloy showed a marked reduction in specific gravity after the addition of any element it was considered that this element could be regarded as a "disturber" element. As a result of many experiments it was noted that when calcium was added a marked reduction in specific gravity took place in a number of alloys, particularly those of aluminium-copper and of zinc.

By the addition of small amounts of calcium to an alloy containing 15 per cent. zinc, a curious surface effect was noticed on chill-cast ingots. This effect consisted in a distinct roughness on the surface of these chill-cast ingots. On closer examination it was noted that this rough surface was due to thousands of minute bubbles, which had appeared on the still molten and pasty surface of the ingot, and had subsequently burst, thus leaving behind vast numbers of minute craters. The alloy while cooling had been expelling this disturbed gas, but had frozen long before this expulsion had been completed. It was then attempted to investigate the effect of passing highly active gases through the molten metal as a means of removing undesirable dissolved gases.

The element chlorine is recognised as being one of the most active elements, especially in regard to hydrogen and most metals. Chlorine gas was therefore passed through the molten alloys. Many interesting results were observed, the most notable of which was the effect of chlorine on aluminium and zinc alloys containing calcium. The following experiments were carried out on an alloy containing 14 per cent. zinc, 0.5 per cent. chromium, 0.2 per cent. silicon, and 0.25 per cent. iron. The casting temperature of the alloy was 730 deg. C., and the temperature of the mould was 100 deg. C. in each case. The first melt was all cast into ingots. *Ingot No. 1:* Part of the above heat was remelted, and when at 750 deg. C. chlorine gas was passed through it for 5 minutes. It was then cast as before. *Ingot No. 2:* Another portion was melted, heated to 750 deg. C., and a small quantity of calcium alloy added, and then it was cast in ingots as before. *Ingot No. 3:* The rest of this heat was remelted, one ingot only was cast. *Ingot No. 4:* The metal remaining in the crucible was gassed with chlorine for 2 minutes, and *Ingot No. 5* cast. The remainder was gassed with chlorine for a further 1½ minutes, and *Ingot No. 6* cast. As the calcium alloy contained considerable quantities of dissolved gases a portion was first treated with chlorine to remove mechanically held gases. A new heat of standard alloy was made up, to which was added a small quantity of the gas-free calcium alloy, ingots were poured as before, becoming *Ingot No. 7.* The various ingots are described as follows:—

No. 1.—During cooling no gas was evolved, the surface was quite clean, with the exception of a few small cavities at the edge. Specific gravity, 3.005.

No. 2.—The surface was whiter. Along the centre portion of the ingot there were only a few isolated crystals. The deep contraction pits as seen in No. 1 were replaced by shallow depressions. Specific gravity, 2.993, representing a fall of 0.02 in specific gravity.

No. 3.—This ingot, while cooling, appeared to be saturated with gas. Thousands of minute bubbles were seen bursting on the surface. Along the centre of the ingot many isolated crystals and deep contraction pits were seen. Specific gravity, 2.959.

No. 4.—The surface was much smoother, but a large number of small bubbles were still to be seen on the surface. The columnar side crystals were now visible. In the centre isolated crystals were seen, while the deep pits were replaced by shallow depressions. Specific gravity, 2.979.

No. 5.—Ingot similar to No. 4. Crystals seen in centre of ingot were much smaller. Specific gravity improved by 0.037. Specific gravity, 2.996.

No. 6.—During cooling no gas was liberated. This ingot was remarkably clean, large columnar crystals were clearly seen. The crystals in the depressions were very small. Specific gravity improved by 0.087. Specific gravity, 3.046.

No. 7.—This ingot showed the characteristic rough surface as in No. 3, but in more accentuated form. Specific gravity, 2.872. On gassing for the proper time the appearance was as seen in No. 6. Specific gravity, 3.042.

From analysis it can be safely concluded that the difference in specific gravity of the samples is not due to a difference in composition.

A comparison of S. L. Archbutt's and the author's results are given below:—

Slow solidification and nitrogen method.		
Alloy.	Treatment.	Gain on Specific Gravity. Per cent.
"Y"	Ingotted, and remelted	0.51
"Y"	Ingotted once remelted .. .. No stirring.	.99
"Y"	Slow solidification and remelted	2.23
"Y"	Slow solidification and nitrogen gassed	2.75
	Maximum gain recorded ..	2.75
	Chlorine method.	
EIIA	Ingotted and remelted	0.61
EIIA	Remelted and gassed 2 minutes	1.01
EIIA	Gassed 2 minutes more ..	2.94
EIIA	Remelted and gassed 4 minutes	6.05
		7.02

Assuming that the calcium alloy could be added without causing preliberation of any gas, the specific gravity of the basic alloy (EIIA) and the calcium added would be approximately 2.985.

Then $3.046 - 2.985 = 0.061 = 2.04$ per cent.

The above amount would represent the actual gain in specific gravity due to gassing with chlorine for a period of 4 minutes.

Similar experiments have been carried out on various alloys with the following results, the procedure in all cases being as follows: A stock of standard alloy was first made up. Some of the stock was remelted and a 1-in. dia. sand-cast bar poured at 50 deg. superheat. Some of the stock was remelted; it was then slowly solidified, remelted, and a 1-in. dia. sand-cast bar poured at 50 deg. superheat. Some of the stock was remelted, chlorine gas was passed through the metal for a period of from 3 to 4 mins., and a 1-in dia. sand-cast bar poured at 50 deg. superheat. Chill-cast ingots were also poured as above.

* A Paper read before the Liverpool meeting of the Institute of Metals.

† Manager, D. and J. Tullis, Ltd., Clydebank.

‡ "Occlusion of Gases by Metals," Trans. Faraday Soc., 1918, 14, 173-293.

§ "Z. Metallkunde," 1922, 14, 227-285.

¶ "J. Inst. Metals," 1925, 33, 227.

Tests on a Silicon-Aluminiun Alloy.

This alloy contained 11 per cent. silicon and about 0.5 per cent. iron as impurity.

11 per cent. Si.	Sp. Gr.	Gain on Sp. Gr. Per cent.
Stock alloy	2.661	—
Remelted stock	2.645	Decrease
Remelted and slowly solidified	2.650	0.180
Remelted and gassed	2.681	1.150

The gassed metal was remarkably smooth; its structure was distinctly modified.

Tests on a Calcium-Aluminium Alloy.

This alloy contained 10.05 per cent, calcium, 0.21 per cent. iron, and 0.24 per cent. silicon. It was very porous.

10 per cent. Ca.	Sp. Gr.	Gain on Sp. Gr. Per cent.
Stock alloy	1.766	—
Remelted stock	2.488	40.8
Remelted and slowly solidified	2.509	0.83
Remelted and gassed	2.580	3.7

On comparing the normal and gassed alloys, it would appear that they were quite different alloys. The surface crystals of the gassed alloy were over ¾ in. in length. On the surface of the normal alloy no crystals were visible.

Tests on a Calcium-Silicon-Aluminium Alloy.

This alloy contained 4 per cent. calcium, 11.2 per cent. silicon, and 0.24 per cent. iron. While cooling this alloy exuded quantities of its eutectic on to the surface of the ingots.

4/11 Ca Si.	Sp. Gr.	Gain on Sp. Gr. Per cent.
Stock alloy	2.352	—
Remelted stock	2.457	4.21
Remelted and slowly solidified..	2.482	1.01
Remelted and gassed	2.592	4.42

Eutectic extrusion was very much reduced in the metal which had been slowly solidified. No extrusion whatever took place in the case of the chlorine-treated metal.

Tests on Pure Aluminium.

This metal contained 99.6 per cent. aluminium along with about 0.2 per cent. each of iron and silicon. The addition of a small amount of calcium as a disturber element was also tried.

99.5 per cent. Al.	Sp. Gr.	Gain on Sp. Gr. Per cent.
Remelted stock	2.693	—
Gassed 10 minutes	2.703	0.37
Calcium, regassed	2.710	0.14

Making due allowance for the calcium contained in melt 3, the actual specific gravity of the aluminium, etc., would be 2.715. Therefore the percentage gain on melt 1 would be 0.82 per cent.

The Aluminium-Iron Alloys.

In these experiments three alloys were made up containing 10, 15, and 20 per cent. of iron. It appears that there are several alloys of aluminium which exude a gas-rich portion while cooling. At present three binary alloys are known to exhibit this property—viz., calcium-aluminium, iron-aluminium, and silicon-aluminium. Ternary alloys containing any two of the elements calcium, iron, or silicon, also exhibit exusion. Of the three binary alloys, the iron alloys are the most persistent in this effect. In the following tests a percentage ratio was taken between the exuded bead of metal and the cast ingot from which it was obtained. This was done to discover which alloy showed the greatest amount of exudation. At the same time the various alloys were treated with chlorine gas in order to ascertain what effect it would have in the exudation phenomenon. The alloys were made up by plunging soft iron wire into molten aluminium at a high temperature. In each case small cone-shaped castings were poured at as nearly as possible the same temperature. A chill- and a sand-casting were poured in each cast. The following results were obtained:—

Alloy.	Casting Temperature. Deg. C.	Percentage of exudation. Sand-cast.	Chill-cast.
10 per cent. Iron.			
Normal	900	7.7	4.0
Gassed 6 minutes ..	900	2.4	1.3
,, 10 ,, ..	900	1.0	Nil
15 per cent. Iron.			
Normal	1,050	10.3	8.3
Remelted	1,000	3.1	1.5
Gassed 10 minutes ..	1,070	2.8	1.6
,, remelted ..	1,060	0.8	Nil
20 per cent. Iron.			
Normal	1,130	6.7	5.0
Remelted	1,110	6.6	5.1
Gassed 6 minutes	1,110	3.8	2.1
,, 4 ,, more	1,110	2.7	1.2
,, 5 ,, ,,	1,110	5.2	3.6

After casting the various alloys, exuded metal appeared at once on the surface of the chill-castings, but in the case of the sand-castings it did not appear for about one minute. The sand-castings exuded much more metal than the chill-castings. During cooling, slight crackling noises were heard at the surface of the castings. These appeared to be caused by gas evolution.

From a study of the observations made on alloys of from 10 to 20 per cent. iron, the following conclusions may be drawn:—(1) The 10 per cent. alloy exhibits about the same amount of exudation as the 20 per cent. alloy, but it is more responsive to chlorine gas treatment. (2) The 15 per cent. alloy appears to exhibit the greatest amount of exusion, but is not readily responsive to gassing treatment. (3) The 20 per cent. alloy is barely affected by gassing with chlorine. (4) In alloys containing more than 10 per cent., it appears necessary to add an element which causes gas disturbance.

Experiments on the Unstable or Disintegrating Alloys.

Certain alloys of aluminium are known to develop age-cracking or disintegration, which occurs after the alloys have been stored for some time. It may take the form of crack development or complete disintegration to a powder. Aluminium-zinc alloys have been reported to develop this defect, but no actual case has come under the author's notice. Spontaneous disintegration does occur in certain aluminium alloys; these alloys belong to a class quite outside the useful range of commercial alloys. They apply solely to the hardener alloys. Aluminium-rich alloys containing cobalt, iron, manganese, nickel, etc., exhibit this phenomenon, and alloys of manganese in particular are prone to disintegration. Alloys containing 25 per cent, and upwards of manganese have been reported to disintegrate. These alloys are extremely hard and brittle and, on standing, first develop cracks, finally falling to powder. Guillet * carried out experiments on alloys which had been aged in dry air, oxygen, nitrogen, and hydrogen. Within seven days disintegration took place in free air, while storage in the above gases prolonged disintegration up to a period of only fifteen days. He is of opinion that the disintegration is due to an allotropic change. The author, on the other hand, believes that it is entirely due to dissolved or combined gases.

Disintegration is, therefore, governed by purity, *i.e.*, freedom from carbides, nitrides, etc. In order to prove this the following experiments were carried out. In the first experiment an alloy containing 25 per cent. of manganese was made up and cast in chill ingots. The aluminium used was 99.6 per cent. purity, and the manganese was carbon-free 98.99 per cent. purity. Melting was done in an electric furnace. After standing for a period of over six months, no cracking or disintegration had taken place. An alloy was then made up containing 60 per cent. of manganese. The alloy was well mixed and a portion was cast in chill ingots. The remainder was returned to the furnace and gassed with chlorine for a period of five minutes, it was also cast in chill ingots at the same temperature. During cooling the untreated alloy cracked into about 35 pieces. On the other hand, the treated alloy cracked much less (about 18 pieces). When fractured cold the untreated alloy emitted a strong smell of hydrocarbon gas, while the treated alloy was practically free from smell. Representative samples of these alloys were stored together. Photographs were taken at intervals of from 6 to 300 hrs. after casting. It was interesting to note that the untreated alloy fell completely to powder in 300 hrs., while the treated alloy only just began to break up into large pieces after the same period of storage.

* L. Guillet, Compt. rend., 1919, 169, 1042-1043.

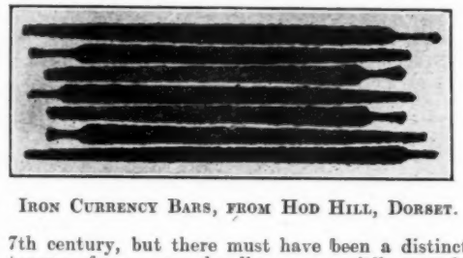
The Breaking of a Currency Bar.

By H. Littlehales.

To not many people does the opportunity arise to see the effect of the fracture of a piece of worked metal 2,000 years after it has left the maker's hands.

Amongst the very oldest of the remains of worked metal in England are the bars of iron which, before the time of the Romans, were in use as money by our British ancestors. Many of these bars remain to-day, though possibly all were made by British craftsmen more than 2,000 years ago.

What these bars were called by those by whom they were used we do not know. It is indeed a very curious fact that we know nothing of the language of the people of this country before the



Iron Currency Bars, from Hod Hill, Dorset.

7th century, but there must have been a distinct tongue, for we can hardly suppose folks merely barked at each other. To-day the bars are called "Currency Bars." We may see them in various museums. All appear to be about a yard in length and something more than an inch in width. They are neither thick nor heavy; indeed, in substance they are much like the old slats of bedsteads. All have the one end finishing with a blunt point, the other being bent round in, as it were, a kind of handle. The late Mr. Hooley a few years ago dug up near Winchester no less than thirteen of these bars, and, relating the story of his excavations in a Paper to the October number of the "Archæological Journal" for 1921, he tells us of the results of the breaking of one of them. On this point, interesting to all ironworkers, Mr. Hooley writes: "A portion of a currency bar which was broken by the spade exhibits a clean, fresh fracture. It is remarkable that the interior appears to be quite unaltered, though there is a thin layer of rust outside. The transverse sections exposed have all the brilliancy of an iron bar just manufactured. The metal has a marked crystalline structure, and on breaking a fragment in a longitudinal direction a similar structure and appearance were revealed. It is very tough, and strongly resists the action of the drill and file."

Our illustration, for which we are indebted to the courtesy of the authorities of the British Museum, shows the common form of the bar.

Messrs. Swan, Hunter & Wigham Richardson, Limited, Wallsend-on-Tyne, have received an order for a passenger steamer 500 ft. in length from a Marseilles firm of shipowners.

Die-Casting of Copper-Rich Alloys.*

By R. Genders, M.B.E., M.Met., F.I.C. ; C. R. Reader, Ph.D., M.Sc. ; and V. T. S. Foster, B.Met.

Introduction.

The die-casting of copper-rich alloys is an industry so far comparatively undeveloped in this country, where its main application is in making small articles in which great strength is not required. In America, on the other hand, large and highly-stressed engineering parts are made on a big scale by die-casting. It is probable that the absence of development here along similar lines is due mainly to the lesser degree of standardisation and mass production, but also to the lack of information concerning the advantages of die-casting, and perhaps to doubt concerning the reliability of die-cast engineering parts. A further factor is the difficulty in manufacture created by the necessarily high casting temperature used. The investigation, portions of which are summarised in this Paper, was undertaken with the object of obtaining information regarding the process of die-casting high melting-point alloys, the material produced, and the possibilities of improvement, the ultimate aim being the widening of the scope of use for die-castings.

Present Methods of Die-Casting.

A description of die-casting practice in this country by Rix and Whitaker,† which appeared in this Journal in 1918, dealt with the methods used commercially and with experimental work leading to the adoption of "aluminium-bronze" containing 1 to 4 per cent. of iron. The position of the process at that date was discussed, and suggestions were made regarding information which might usefully be obtained concerning the properties of the materials used. More recently G. Mortimer. has given a wide survey of the subject of die-casting, describing all the methods commercially in use and giving much detailed information as to the best modern technique in the gravity die-casting of aluminium alloys. This information is of direct application to the die-casting of high melting-point alloys.

At present "aluminium-bronze" with or without added iron is almost the only copper-rich alloy die-cast. Brass of about 60:40 composition has been used recently but comparatively rarely. The alloy to be cast is melted and transferred to a maintaining or storage furnace, where it is held at the desired casting temperature, and from which it is removed, as required for casting, by small hand-ladles. The moulds are generally of grey cast iron, sometimes with steel inserts, and the cores are made from special steels of the heat-resisting type. In general features the moulds used are of the same type as those described and illustrated in the Paper by Mortimer. The range of castings which can be made successfully in "aluminium-bronze" is, however, perhaps smaller than is possible with aluminium alloys, though castings of very complex form are regularly made in the higher melting-point alloy. Only the method of gravity casting can be employed in the die-casting of "aluminium-bronze" and brass. Pressure casting is impossible on account of the high temperature necessary. In the casting operation the metal is poured rapidly from the ladle into the mould, which is then immediately opened and the casting ejected. Solidification is extremely rapid, and for complicated moulds the alloy is considerably superheated to enable the mould to be completely filled. Records from one works showed the casting temperature of "aluminium-bronze" to vary between 1,150 and 1,300 deg. C. In general practice the surface of the mould is not treated; the cores are dipped after each casting in a plumbago wash. The moulds are initially heated, and during repeated casting attain a fairly steady temperature of 200 to 300 deg. C.

Difficulties met with in manufacture are mainly in the avoidance of short-run castings, drossy surface appearance under the runner, local shrinkage on the surface, and local pitting due to the "blowing" of the mould. It is understood that brass die-castings show these types of defect much more readily than those made in "aluminium-bronze." Brass, however, possesses the advantage of ease of machining and soldering.

A number of commercial die-castings (varying in weight from 4.5 to 616 grms.) which have been examined all showed some local unsoundness, as would be expected, near changes of section, due to the "drawing" commonly a source of defects in all types of casting. The cavities, however, generally occur mainly in the portions of thicker section, and in many cases probably do not greatly influence the strength of the casting as a whole. A casting of uniform section was found to be practically sound. The surface quality of all the castings was good, but those made of brass were inferior to those of "aluminium-bronze." Table I above gives the properties and composition of a representative selection of castings from three works. The tensile tests were made on small test-pieces of 0.75 to 1 in. acting length cut from suitable portions of the castings.

The above results show the castings to vary considerably in composition and hardness, but demonstrate that it is possible to produce die-castings possessing a high degree of strength and good surface quality in the alloys at present in use.

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TABLE I.—*Composition and Properties of Representative Die-Castings.*

R.D. Mark.	Copper. Per cent.	Aluminium. Per cent.	Zinc. Per cent.	Iron. Per cent.	Density. Grm. per c.c.	Approximate maximum density of same alloy.	Brinell hardness number. Average. 5-mm. ball, 250-kg. load.	Maximum load. Tons/in.²
ENR 1 ..	59.5	<0.1	40.1	0.32	8.329	8.38	112	24
,, 2 ..	61.5	<0.1	37.2	1.30	8.394	—	95	—
,, 3 ..	61.4	<0.1	38.0	0.61	8.340	8.39	95	25
,, 4 ..	90.3	9.5	—	Nil	7.578	7.65	112	30
,, 5 ..	90.0	9.8	—	Nil	7.625	7.59	114	—
,, 6 ..	91.9	8.0	—	Nil	7.808	7.80	66	22
,, 7 ..	89.4	10.1	—	Nil	7.531	7.57	114	—
,, 8 ..	90.5	9.4	—	Nil	7.630	7.67	115	—
,, 9 ..	89.4	9.8	—	Nil	7.545	7.59	136	—
,, 10 ..	89.6	9.0	—	1.53	7.635	—	119	—
,, 11 ..	87.7	10.6	—	1.96	7.457	7.48	191	43
,, 12 ..	90.2	8.5	—	1.64	7.627	—	120	—
,, 13 ..	89.4	9.3	—	1.40	7.584	—	122	40
,, 14 ..	90.4	8.2	—	1.15	7.651	—	129	—
,, 15 ..	88.4	10.8	—	0.8	7.478	—	192	—
,, 16 ..	86.2	10.9	—	2.7	7.271	—	248	—
,, 17 ..	88.0	10.7	—	1.4	7.364	—	220	—
,, 18 ..	87.5	10.9	—	1.7	7.454	—	245	—
,, 19 ..	87.3	10.2	—	2.3	7.446	—	165	—
,, 21 ..	87.2	9.9	—	2.6	7.463	—	141	—

ALLOYS.

The Properties of Selected Alloys as Chill-Cast Bars and as Die-Castings.

The experimental procedure followed has been in the first place to survey, under comparative conditions, the properties of several series of binary and ternary alloys, based on alloys possessing good properties and already used commercially for various purposes. As a basis on which to consider the properties of the alloys when die-cast, tests were first made on small cylindrical chill-castings from which the required test-pieces were machined. On these results a selection was made of the most promising of the alloys for further examination in the form of die-castings. The mould used for die-casting was made so as to provide a flat and a round tensile test-piece with a small amount of material for other tests.

Chill-Cast Bars.

The alloys examined as chill-castings were:—(*a*) The "aluminium-bronzes" with added iron; (*b*) the "aluminium-bronzes" with added nickel and with nickel and iron; (*c*) "aluminium-bronzes" containing manganese and manganese and iron; (*d*) complex "aluminium-bronzes"; (*e*) brasses with added iron; (*f*) brasses containing nickel; (*g*) high-tensile brasses; and (*h*) nickel brasses with added aluminium.

The mould used was a hollow cast-iron cylinder, closed at one end, giving an ingot 8 in. in length, tapered from a diameter of 1 in. at the bottom to 1.1 in. at the top. The mould thickness adopted throughout was 0.5 in.

Each ingot was cast from the crucible, and a fireclay sinking-head 2 in. in depth was used to ensure complete feeding. The casting temperature used was approximately 150 deg. C. above the liquidus of each alloy. A uniform pouring rate of 3 to 4 seconds was adopted. In the majority of cases duplicate bars were prepared.

From each ingot was machined a tensile test-piece (acting length 2 in., diameter 0.564 in.), a cylinder 0.798 in. in diameter and length, and a transverse slice 0.25 in. in thickness. Density was determined on both the machined tensile test-piece and on the cylinder. Brinell hardness tests (5-mm. ball, 250-kg. load) were made on the transverse slice. The load which produced a permanent extension of 0.15 per cent., or 0.003 in. on 2 in., the maximum extension allowed on application of the "proof-stress," as specified by the British Engineering Standards Association, was taken as the "maximum proof stress."

The results show the alloys dealt with to be capable of giving an extensive range of properties, a number of the alloys being considerably stronger in the chill-cast state than the average die-casting.

Experimental heat-treatments carried out on a large number of duplicate cast bars showed that generally the mechanical qualities were near the maximum in the chill-cast state.

Die-Cast Test-Pieces.

The mould used for the determination of the properties of alloys as die-castings was designed

* Extracted from a Paper presented to the Liverpool meeting of the Institute of Metals. The authors are on the Metallurgical Staff of the Research Department, Woolwich.

† "J. Inst. Metals," 1918, 19, 123-131.

‡ *Ibid.*, 1926, 35, 371.

XUM

to give a casting representing a flat tensile test-piece attached at the ends to a round test-piece 0.564 in. in diameter (see Fig. 1). The complete casting was about 1.5 lb. in weight. The mould was made of cast iron and was constructed by a die-casting works. Originally the "gate" was placed so that the metal entered at the thin section (position 1, Fig. 1), in accordance with the practice, often necessarily followed, of placing the "gate" where the subsequent removal of the head can be effected economically and without injury to the appearance of the casting. It appeared probable, however, that this position would not be the most satisfactory from the point of view of soundness. Tests made on a number of alloys showed some irregularity in properties, and the range of casting temperature giving complete castings was limited. All the castings showed unsoundness, generally in the form of large cavities of the "draw" type occurring mainly in the thick section at the ends of the round test-piece. Further tests were accordingly made to compare the effects of placing the gate at different positions in the moulds.

With the gate at one end of the mould (position 2, Fig. 1), so that the metal entered both thick and thin sections at the same time, the castings were less unsound than the previous series, the useful range of casting temperature was widened, and the properties of the castings were more regular, but the surface was less satisfactory. The method of bottom casting was found unpromising. Maximum improvement in all respects was obtained by placing the gate so that the metal entered only at the thickest section of the casting (position 3, Fig. 1), and this method was finally adopted. The castings were of good surface quality, regular in properties, and showed little unsoundness, while the useful range of casting temperature was near the maximum given by any of the modifications tested.

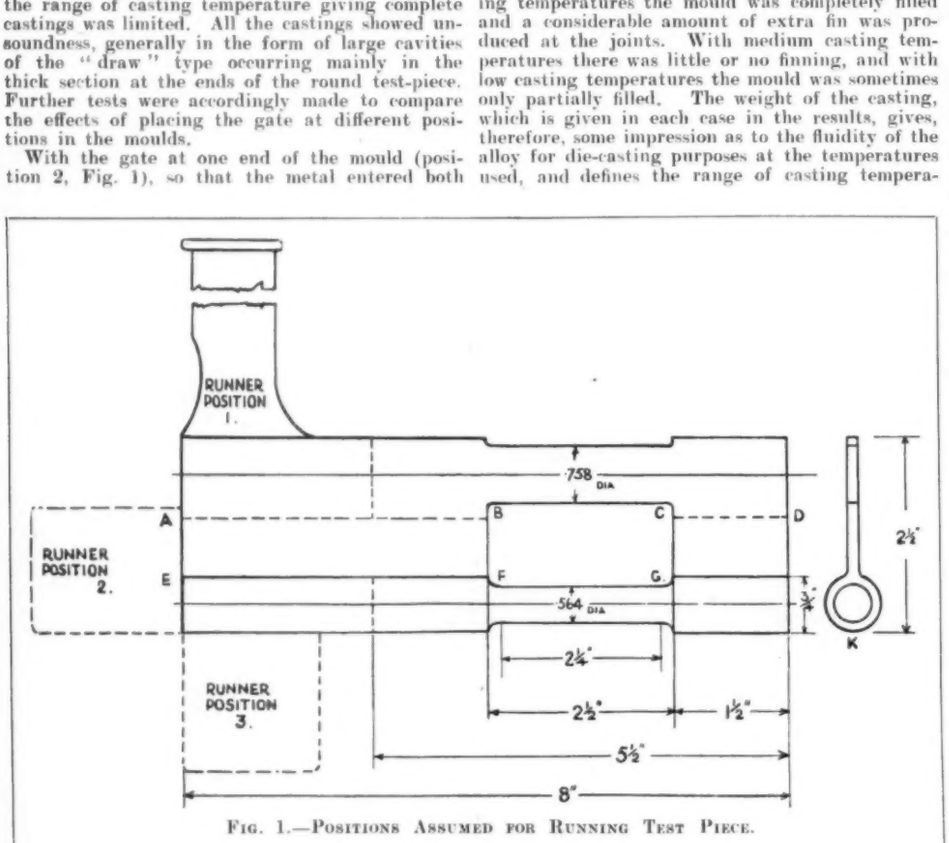

FIG. 1.—POSITIONS ASSUMED FOR RUNNING TEST PIECE.

Sections of die-cast test-pieces, showing the effect of the position of the gate on the internal soundness of the casting were examined and reported upon.

Casting Methods.

In general, the methods employed in casting were very similar to those in industrial practice, except that the main body of molten metal was allowed to cool between successive castings in order to provide a range of casting temperatures. Sufficient alloy for eight die-castings was melted in a crucible, removed from the furnace, and poured in separate lots into a small preheated crucible which acted as a hand-ladle. From the hand-ladle the metal was poured rapidly into the mould, which was opened and the casting ejected, immediately after the solidification of the runner. Eight castings were made in succession as rapidly as possible, continuous temperature readings being made of the metal in the large crucible. Before each series of castings the mould was heated to 200 to 250 deg. C. At the end of a series the temperature of the mould was found to be in the neighbourhood of 300 deg. C.

The mould was brushed clean after each series, but received no further preparation. A series of eight castings could be made in an average time of five minutes. The two halves of the mould were held together by a spring clamp. With high casting temperatures the mould was completely filled and a considerable amount of extra fin was produced at the joints. With medium casting temperatures there was little or no finning, and with low casting temperatures the mould was sometimes only partially filled. The weight of the casting, which is given in each case in the results, gives, therefore, some impression as to the fluidity of the alloy for die-casting purposes at the temperatures used, and defines the range of casting temperature in which a complete casting, with little fin, can be produced in a mould of the type employed.

Alloys Tested.

The alloys selected for examination in the form of die-cast test-pieces were of the following types:—

(1) "Aluminium-bronze"; (2) "aluminium-bronze" with varying percentages of added iron (the above alloys represent the range of composition at present in use for die-castings); (3) "aluminium-bronze" containing 2 per cent. lead (this alloy has been referred to as having been used in America); (4) "aluminium-bronze" containing about 7.5 per cent. nickel; (5) "aluminium-bronze" containing iron and manganese; (6) high-tensile brass (copper 58 per cent., zinc 35 per cent., aluminium 3 per cent., and manganese 4 per cent.); and (7) aluminium-nickel-zinc-copper alloy.

Die-Casting in Commercial Moulds.

All the types of alloy examined have been used in the manufacture of die-castings in moulds of various designs, on an experimental scale. In each case good die-castings could be produced. In view of the promising results given by the high-tensile brass a further test was made in a die-casting works on a large variety of moulds normally used for the die-casting of "aluminium-bronze." In several cases the mould appeared equally suitable for "aluminium-bronze" and high-tensile brass, while in others slight modifications to ordinary practice were indicated to be desirable. The alloys containing zinc showed less "fluidity" than those based on "aluminium-bronze," and consequently required in some moulds a runner of larger cross-section.

The results of the exploratory work suggest that a large range of useful alloys is available for adaptation to die-casting manufacture, fulfilling requirements for materials either of low strength with high ductility, medium strength with medium ductility, or high strength with low ductility. The alloy containing 1.5 per cent. of aluminium with iron and manganese was observed to give particularly good surface quality.

The effect of added iron up to about 4 per cent. on "aluminium-bronze" is to increase the maximum proof stress and tensile strength of the die-cast alloy. Nickel added to the extent of about 10 per cent. raises the maximum proof stress to a greater extent, but is accompanied by a marked lowering of the ductility. The addition of iron and nickel together to 12 per cent. "aluminium-bronze" produces a strong alloy having a tensile strength of about 50 tons per sq. in.; this type of alloy was the only one tested showing distinct liability to cracking in the double test-piece mould. The total shrinkage of this alloy (about 2.4 per cent.) is greater than that of all the remaining types tested ("aluminium-bronze" about 2 per cent., high-tensile brass about 1.9 per cent.), and its utility would probably be limited to castings of simple form. "Aluminium-bronze" is weakened slightly by the addition of lead, which also appears to introduce small surface defects. The high-tensile brass included in the tests showed mechanical qualities as high as those of the alloys related to "aluminium-bronze." The nickel-brass (Cu-Zn-Ni alloy) containing aluminium gave a high ratio of proof stress to breaking load.

The machining qualities of the alloys have not been considered in detail, but none of the castings made gave any great difficulty in turning or sawing. The "aluminium-bronze" containing lead appeared slightly easier to machine than the other alloys.

Aluminium-Brasses.

The foregoing results, and work on the resistance of mould and core materials to attack by molten alloys to be described later, suggest that, from several points of view, special brasses may have distinct advantages as die-casting alloys. The high-tensile brass giving promising results in the form of die-cast test-pieces contained aluminium and manganese, and gave a tensile strength in the die-cast condition of the order of 40 tons per sq. in., with a proof stress of about 26 tons per sq. in. Where good mechanical qualities are required this alloy appears suitable for adoption, but for a large number of purposes where strength is not the primary consideration it has the disadvantages of a slightly higher cost and more complicated composition than the aluminium-bronzes normally used. Since aluminium alone is known to confer a high degree of hardening on copper-zinc alloys, and to give, under proper conditions, good surface quality and resistance to corrosion, the aluminium-brasses were selected for further investigation, with the object of determining whether suitable die-casting alloys of simple composition, alternative to "aluminium-bronze" as regards properties, and permitting economy in the wear of moulds and dies, were available. Earlier investigations on the aluminium-brasses were made by Guillet and Cavalier, who estimated the zinc equivalent of aluminium. Carpenter and Edwards* later made a metallographical survey of the copper-rich region of the ternary system and showed that the coefficient of equivalence was variable, being different for the α and β constituents. Records are available of the mechanical properties of various aluminium-

* H. C. H. Carpenter and C. A. Edwards, "The Liquidus Curves and Constitutional Diagram of the Ternary System Aluminium-Copper-Zinc (Rich Copper Alloys)," "Internat. Z. Metallographie," 1912, 2, 209.

brasses;† Smalley‡ has published a series of tests on cast high-tensile alloys, including some aluminium-brasses. The properties of cast and cold-worked high-copper aluminium-brasses have also been investigated in connection with another research.§ In that investigation, however, ductility was of primary importance and copper contents up to 78 per cent. were employed. The present work deals with alloys containing 70 per cent. copper or less, since, although a certain degree of ductility is desirable in a die-casting, this property is subordinate to tensile strength.

The Properties of Chill-Cast Bars.

Three series of alloys were made, showing the effect of increasing aluminium replacing zinc, in brasses containing 70, 60, and 55 per cent. copper respectively.

Duplicate bars 1 in. in diameter were cast in iron moulds, using a fireclay "dozzle," the procedure being similar to that already described. Tensile test-pieces were machined from each bar, and Brinell hardness tests and micro-examination were made on transverse sections.

In view of the probable importance of the length of temperature range over which the alloys exist in the semi-liquid ("pasty") state, the liquidus and solidus of those alloys containing 69.5 per cent. copper with 4.1 per cent. aluminium, and 60.5 per cent. copper with 4.1 per cent. aluminium, were determined as accurately as possible by means of heating and cooling curves. The results shown in Table II were obtained.

The freezing range of both alloys is shown to be about 30 deg. C. An interesting feature observed during the experiments was that in the 70 per cent. copper alloy, when liquefied, the aluminium-oxide skin prevented coalescence of the small pieces used, and stirring was necessary. In the 60 per cent. copper alloy coalescence took place readily without stirring.

TABLE II.

	Cu, 69.5. Al, 4.1.		Cu, 60.5 Al, 4.1.	
	Cooling, deg. C.	Heating, deg. C.	Cooling, deg. C.	Heating, deg. C.
Commencement ..	957	938	931	912
Maximum arrest ..	952	948	927	921
End	921	971	892	944

The addition of aluminium to the brasses was shown to produce a marked effect on the properties of the alloys. In the 70 per cent. and 60 per cent. copper alloys the tensile strength reaches a maximum of about 40 tons per sq. in., with a maximum proof stress of over 20 tons per sq. in. When 4.2 per cent. aluminium is present appreciable ductility is retained in the strongest of the alloys. With an aluminium content above 4.2 per cent. both tensile strength and ductility diminish, though the maximum proof stress is again raised.

In comparison with aluminium-bronzes cast under similar conditions the alloy containing 60 per cent. copper and 3.4 per cent. aluminium is superior in strength and of about equal ductility; that containing 70 per cent. copper and 3.4 per cent. aluminium is slightly lower in tensile strength, higher in maximum proof stress, and considerably higher in ductility. These two alloys appear to provide useful alternatives to "aluminium-bronze," while the alloy with 70 per cent. copper and 4.2 per cent. aluminium gives properties intermediate between those of "aluminium-bronze" and of the high-tensile brass previously investigated, the chief features of the alloy being a high proof stress accompanied by appreciable ductility. The alloys containing 55 per cent. copper with aluminium possess properties inferior to those higher in copper.

† M. Thibaud, "High Strength Brasses," Met. Ind. (Lond.), 1925, 27, 435. Abstract of Paper to Franco-Belgian Foundry Congress.

‡ O. Smalley, "Development and Manufacture of High Tenacity Brass and Bronze," Met. Ind. (Lond.), 1922, 21, 75. O. Smalley, "Special Nickel-Brasses," Trans. Amer. Inst. Min. Met. Eng., 1926, 73, 799.

§ R. Genders, "The Ductile Aluminium-Brasses," Brit. N.-F. Metals Res. Asso. Report, No. 46, 106.

The Properties of Die-Cast Test Pieces.

Two alloys, containing 70 per cent. copper with 4.2 per cent. aluminium, and 60 per cent. copper with 3.5 per cent. aluminium respectively, were selected for tests on die-cast test-pieces. The mould, shown in Fig. 1, giving combined round and flat test-pieces was used, and a series of castings at different casting temperatures was made from each alloy.

The properties of the die-cast test-pieces are slightly inferior to those of the test-pieces machined from chill-cast bars, probably owing to a small degree of unsoundness present in the die-castings.

Behaviour in Die-Casting.—Die-castings of commercial form were made from both alloys at a casting temperature of 1,050 to 1,100 deg. C. and with a mould temperature of about 300 deg. C. Since these alloys, when molten, form a thin protective surface layer of aluminium oxide, no flux covering is required in melting, and zinc is vaporised so slowly that there is little difficulty in skimming and manipulating the metal generally. Complete castings of good surface quality, comparable with that of "aluminium-bronze," were obtained. Further tests in works have shown, however, that in some moulds having pronounced changes of section, where some unsoundness in the casting is inevitable, the aluminium-brasses show a greater tendency than aluminium-bronze to surface contraction or "drawing."

Regularity of Properties.—Regularity tests were made on the alloy containing 60 per cent. copper with 3.5 per cent. aluminium, in comparison with the high-tensile brass alloy, containing aluminium and manganese, previously dealt with. Twelve castings of each alloy were made in succession in the double test-piece mould from the same charge of metal. The results of tests on the castings are given in Table III.

TABLE III.—*Regularity of Properties of Die-Cast Test-Pieces.*

	A. Aluminium-Brass. Cu., 59.9 per cent.; Al., 3.5 per cent.; Zn. remainder.		*B.* High-Tensile Brass. Cu., 57.6 per cent.; Al., 3.2 per cent.; Mn., 4.1 per cent.; Zn. remainder.	
	Round Test-Piece.	Flat Test-Piece.	Round Test-Piece.	Flat Test-Piece.
Maximum proof stress. Tons/in.²:				
Average of 12 tests ..	20.7	17.5	26.2	22.2
Maximum ..	21.4	18.6	26.9	24.4
Minimum ..	19.5	16.1	25.4	16.0
Maximum load:				
Average of 12 tests ..	38.9	29.9	39.6	31.2
Maximum ..	42.0	33.2	41.7	36.1
Minimum ..	32.5 (Broke through blowhole) (Next lowest 37.8)	26.7	33.3	25.8

A—Casting temperature, 1030 to 1050 deg. C. Mould temperature, 210 deg. C.

B—Casting temperature, 1,075 deg. C. Mould temperature, 180 deg. C.

The results indicate the probability that under industrial casting conditions the aluminium brasses are capable of giving a product of fairly regular properties and are only slightly inferior, in the die-cast condition, to the more complicated high-tensile brass previously investigated.

Fatigue Tests.—In view of the marked degree to which "aluminium-bronze" is capable of resisting fatigue stresses, comparative tests were carried out on a 10 per cent. "aluminium-bronze," and the suggested alternative aluminium-brass alloys containing 70 per cent. and 60 per cent. copper, with 3.5 per cent. aluminium. The test-pieces were cylindrical bars of standard type, machined from chill-cast 1-in. bars. The 70 per cent. and 60 per cent. copper-aluminium brasses gave fatigue limits of about 10 and 7 tons per sq. in. respectively. "Aluminium-bronze" gave a value of 13 tons per sq. in. Pure 70: 30 brass, free from aluminium, has a fatigue limit of only about 4 tons per sq. in.

Colour and Corrosion Characteristics.

The alloys containing about 70 per cent. copper were all of the normal yellow brass colour, possessing a surface sheen due to the effect of aluminium. The 60 per cent. copper alloys, however, showed a progressive colour change from yellow to red with increase of aluminium content. With an aluminium content above 3.5 per cent. the alloys have a rich red colour, and the 4.2 per cent. aluminium alloy may be easily mistaken for pure copper.

Specimens of brasses containing aluminium and of 10 per cent. "aluminium-bronze" were included in some corrosion trials made in connection with another research. Small plates of the alloys were subjected for three months to the effect of the local atmosphere, alternate wet and dry sea-water test, and total immersion in sea-water; and for lesser periods to the attack of ammonia vapour, nitric acid vapour, and salt spray. In most cases, the aluminium-brasses were more resistant to corrosion than pure brass, and not inferior to "aluminium-bronze." The brasses of high copper content were superior to those containing 60 per cent. copper and below.

Metallographic Characteristics.

While the structures are generally similar to those of the pure brasses, the phase fields are shown to be modified by the presence of aluminium. The modification is similar, but not uniformly proportional to that which would be caused by a higher zinc content.

An interesting feature of the series is the narrowness of the range of composition of the β phase in the alloys containing about 70 per cent. copper, and the more extensive range of the same phase in the 60 per cent. copper alloys.

It appears probable that above 70 per cent. of copper there is a region of transition from the phase fields associated with this portion of the copper-zinc system to the eutectoid of the type found in the copper-aluminium system. An independent survey of this area is projected.

Although the idea of an equivalence value of zinc for aluminium may have a practical appeal, there is no doubt, from the results of Carpenter and Edwards, and the present work, that no uniform equivalent can usefully be adopted. The aluminium content of these alloys for die-casting is limited to that which gives a constitution about mid-way across the $\alpha + \beta$ field. The 60 per cent. copper alloys consist mainly of β, and their tensile strength shows little variation.

Increase in aluminium content, *i.e.*, towards the $\frac{\beta}{\beta+\gamma}$ boundary, results in increased proof stress and diminished ductility. The alloys lying in the $\beta + \gamma$ area of the diagram are poor in mechanical qualities, owing to the brittleness of the γ constituent; compositions outside the β area in this direction should be avoided in practice.

Owing to the rapid rate of cooling in chill moulds, the die-cast or chill-cast alloys are not in a state of equilibrium. In those which were not convertible entirely to β by quenching, specimens of the chill-cast alloys were heated for long periods in a thermo-statically controlled furnace.

Mould and Core Materials.

The construction of moulds and the repair of moulds and cores are important items in the cost of manufacturing die-castings, and in the case of alloys of high melting point may sometimes seriously reduce the saving of cost over other processes, such as sand-casting, stamping, etc. Economy in moulds and cores may thus be a considerable factor in extending the use of die-castings of these alloys.

Moulds now in general use for die-castings are made from cast iron, in which the required form is machined direct or partly built up by means of steel inlays. No definite type of cast iron is specified, the quality of the material being left to the

ironfounder. Wear occurs on cast-iron mould surfaces mainly in the direct path of the stream during pouring.

Cores are always made from steel, generally of the special heat-resisting type, and the same material is used for mould inlays. Works service tests have been made on a number of steels, and it is concluded from the information available that while materials such as high-speed steel and stainless steel are more satisfactory than plain carbon steels, they do not approach in serviceability the high-chromium alloy steels introduced specially for heat-resisting purposes. Deterioration of cores occurs by erosion, by the welding on of the cast metal, and by tensile stresses set up in liberating the hot core after each casting. In some instances pronounced necking of the core is produced; after this stage it become almost impossible to liberate the core, and replacement is necessary. Data as to the lives of cores vary greatly and do not refer to comparative conditions. It is clear, however, that with copper alloys, steel cores deteriorate at least four or five times as rapidly as with aluminium or low melting-point alloys, some showing extraordinarily short lives of the order of 5 to 10 castings.

Table IV.—*Analyses of Materials Tested.*

No.	Type of material.	C.	Si.	Mn.	S.	P.	Ni.	Cr.	Other elements Per cent.
1	Armco iron ..	0.03	>0.01	0.02	0.002	0.013	—	—	Cu 0.11
2	Carbon steel ..	0.42	0.13	0.80	0.036	0.037	—	Tr.	—
3	Carbon steel ..	0.64	0.09	0.30	0.02	0.025	—	Tr.	—
4	Carbon tool steel ..	1.02	0.08	0.28	0.037	0.025	—	—	—
5	Cast iron	3.38 total 3.19 graphite	1.80	0.45	0.10	0.56	—	—	—
6	Cast iron	3.7 total 3.23 graphite	2.25	0.33	0.072	0.39	—	—	—
7	"Semi-steel"	3.26 total 2.47 graphite	1.43	0.96	0.071	0.046	—	—	Cu 0.03 Ti 0.046 A 0.02
8	Nickel steel ..	0.31	0.13	0.65	0.032	0.027	3.66	—	—
9	Nickel-chromium-steel	0.21	0.13	0.33	0.025	0.025	3.78	0.56	—
10	Nickel-chromium-molybdenum steel	0.28	0.15	0.48	0.032	0.028	2.45	0.65	Mo 0.43
11	Nickel-chromium vanadium steel	0.37	0.12	0.21	0.037	0.026	2.66	1.22	V 0.62
12	Nickel-tungsten steel	0.30	0.08	0.20	0.036	0.022	3.40	—	W 1.65
13	Stainless iron ..	0.10	0.08	0.26	0.04	0.017	0.15	12.85	—
14	Stainless steel ..	0.43	0.13	0.20	0.08	0.024	0.20	12.37	—
15	High-speed steel ..	0.48	0.05	0.04	0.046	0.021	—	3.87	W 17.5 V 0.43
16	Heat-resisting steel	0.49	1.98	0.60	0.019	0.027	12.6	12.6	W 2.40
17	Chromium-iron-nickel alloy ..	—	—	1.0	—	—	61.8	14.4	Fe 21.2
20	Special steels for high-temperature service	0.37	0.11	1.3	0.02	0.03	35.6	11.0	—
21		0.41	1.38	1.39	0.01	0.03	26.5	13.4	W 3.54
22		0.15	0.16	0.11	0.005	0.018	7.8	19.8	Co 0.04
23		0.14	0.43	0.20	0.02	0.03	10.6	15.9	Co 0.02
24		0.46	9.20	4.90	0.01	0.024	14.6	0.09	Co 0.01
25		0.41	0.79	0.75	0.01	0.029	22.6	5.7	Co 0.12
26		0.55	3.53	0.59	0.01	0.021	0.10	9.06	Co 0.01
27	Chromium-molybdenum steel ..	0.33	0.06	0.17	0.037	0.029	0.05	2.03	Mo 0.54
28	Invar	Tr.	0.30	0.13	0.01	0.01	34.7	0.26	—
29	Nickel-chromium alloy ..	Tr.	—	0.60	—	—	78.1	19.7	Fe 1.5
30	Stellite	2.2	—	Nil	—	—	1.5	29.7	Co 52.0 W 9.7 Fe 5.0

Experimental Work.

(*a*) *The Effect of Immersion in Molten Alloys at Rest.*—Bars 0.5 in. in diameter and 3 in. in length were prepared from 17 different materials. These comprised two varieties of cast iron, a semi-steel, three samples of steel used currently by manufacturers, and 11 other steels representing most of the known types. The compositions of all the materials are shown in Table IV. In view of the fact that pure chromium had been found in former experiments on high-tensile alloys to be almost completely insoluble in "aluminium-bronze" at ordinary melting temperatures, a bar of plain carbon steel and one of Armco iron were electro-plated with a film of chromium 0.002-0.003 in. in thickness and tested in comparison with the other materials.

The machined bars were luted at one end into holes (0.5 in. apart) in a moulded carborundum block, and the whole immersed in a bath of molten alloy for one hour. Aluminium-bronze (10 per cent. Al) and 60: 40 brass were selected as typical alloys. They were melted in an electrically heated furnace, and during the immersion were maintained at a temperature of 1,100 deg. and 1,000 deg. C., ± 10 deg. C., respectively.

On removal from the bath, the bars were cooled in air. A considerable amount of alloy remained adherent on the surfaces of the bars and, except with the more resistant of the materials, was not completely detachable either by mechanical means or by electrolytic treatment. Estimation of the degree of deterioration due to immersion could not, therefore, be determined by weighing, and a method of measurement was adopted. Each bar was cut transversely into four equal parts and the mean diameter of the portion remaining unattacked determined by means of a measuring microscope. From this the mean diameter of the whole bar was ascertained. The results of duplicate experiments are given in Table V.

The Effect of Immersion in Molten Alloys in Motion.

A further series of tests was made on similar lines to those described above, but with the added factor of continuous motion of the molten alloy. Some further materials, including calorised steel, were added to those previously tested, and more detailed tests were made on chromium-plated steel.

Machined bars of the materials to be tested, 3 in. in length and 0.5 in. in dia., were assembled in a steel frame. This arrangement gives support to the bars at both ends. The frame was immersed in a bath of molten alloy in an electric tilting furnace for one hour, and throughout this period the furnace was tilted alternately backwards and forwards to maintain a continuous flow of the metal over the specimens. On removal from the bath the frame containing the specimens was cooled in air. The average diameter of the unattacked remainder of the bars was determined as before.

In addition to the 19 materials dealt with in the previous tests, a number of new materials were included. The compositions of these are also shown in Table IV.

Table V.—*Reduction in Diameter of Bars after Immersion in Molten Alloy. Original Diameter of Bars,* 0.5 *in.* (1.27 *cm.*).

*	After Immersion in 10 per cent. "Aluminium-Bronze" at 1,100° C. for 1 hr.		After Immersion in Molten 60: 40 Brass at 1,000° C. for 1 hr.	
	First Experiment.	Second Experiment.	First Experiment.	Second Experiment.
	Cm.	Cm.	Cm.	Cm.
1	0.13	0.07	0.04	0.03
2	0.22	0.15	0.04	0.03
3	0.07	0.07	0.02	0.04
4	0.09	0.05	0.02	0.03
5	Broken when removed from molten metal.		0	0
6	0	0	0	0
7	0	0	0	0
8	0.19	0.20	0.05	0.04
9	0.25	0.21	0.05	0.03
10	0.24	0.15	0.03	0.04
11	0.11	0.11	0.01	0.03
12	0.15	0.18	0.03	0.03
13	0.03	0.03	0.01	0.02
14	0.02	0.05	0.01	0.02
15	0.04	0	0.01	0.02
16	0	0	0	0.01
17	0.09	0.10	0	0.07
18	0	0	0.01	0.01
19	—	—	0.02	0.02

* See Table IV for type of material designated. Nos. 18 and 19 respectively represent chrome plated steel and chrome plated Armco iron.

The molten alloys were, as before, "aluminium-bronze" at a temperature of 1,100 deg. C. and 60: 40 brass at 1,000 deg. C.

In general, it is indicated that materials which are attacked to an appreciable extent by molten "aluminium-bronze" at rest are attacked more intensively when the alloy is in motion. Those having a high resistance to attack are little affected by flow of the alloy in which they are immersed. These results suggest that flow such as that operating in the tests does not produce mechanical erosion, but serves principally to maintain a constant rate of solution of the bars by preventing the molten alloy in contact with them from becoming saturated. Comparison of the behaviour of Armco iron and the three plain carbon steels shows that the rate of attack decreases with increasing carbon content, the attack on the 1.5 per cent. carbon steel being very small. The engineering steels containing low percentages of special elements showed rapid deterioration, but steels of the type known as "heat resisting," containing large percentages of alloying elements, were in all cases little attacked. As in the previous tests, cast iron containing 0.59 per cent. of phosphorus, although not dissolved by the molten metal, showed collapse owing to partial melting. The cast irons of lower phosphorus content were not appreciably affected. The main point of difference between the three materials was that of phosphorus content. Up to a certain amount, dependent on several factors, but generally about 0.3 per cent., phosphorus in cast iron does not form the constituent known as "phosphide eutectic." This constituent melts in the region of 950 deg. C., and the immersion tests suggest that its presence was the cause of the rapid deterioration at 1,100 deg. C. of the cast iron containing 0.56 per cent. phosphorus. It would appear to be important that cast iron used for dies should be low in phosphorus content, preferably a pure hematite iron. Nickel-chromium alloys and stainless steel were slightly attacked. Chromium-plated bars of iron and steel showed complete protection over most of the surface, but local attack

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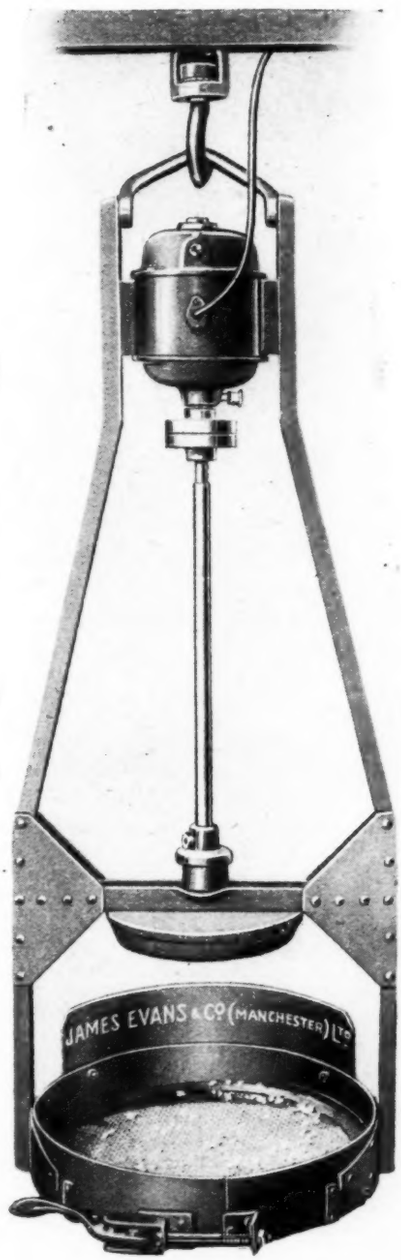

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had occurred in small areas, probably due to some local defect in the plating.

The action of molten 60: 40 brass at rest on all the materials tested has previously been shown to be very small, and the present tests have indicated that it was not appreciably increased by the more severe conditions imposed. The results generally emphasise the low rate of attack of brass compared with "aluminium-bronze."

Further Tests on Protective Coatings of Chromium.

In previous tests on chromium-plated bars a thickness of coating of 0.002 in. was used. A further series of tests was made, using eight bars of Armco iron having electro-deposited coatings of chromium of thicknesses increasing in successive steps of 0.001 in. from 0.001 to 0.008 in. These were immersed in "aluminium-bronze" at 1,100 deg. C. for 3 hrs., the molten alloy being in continuous motion throughout the test. An unplated bar of Armco iron was included for comparison.

On removal of the specimens from the bath it was found that the unplated bar had completely dissolved. The plated bars were practically unattacked except that having a coating 0.007 in. in thickness, which showed local attack at one point where the chromium appeared to have broken. The results of the tests indicate that a very thin deposit of chromium, if continuous and adherent, is efficient in providing protection against molten "aluminium-bronze."

Works tests on chromium-plated cores and moulds have indicated that although the coating offers complete protection, the unequal heating to which it is subjected leads to its removal by flaking. The full practical utility of this method of protection will thus depend on the further improvement in the adhesion of electro-deposited coatings.

Tests on Calorised (Aluminised) Steel.

The treatment known as "calorising" or "aluminising" consists in the heating of iron or steel in contact with materials containing aluminium in an inert atmosphere. A skin of alloy which has a high resistance to oxidation in air at high temperatures is formed on the treated article. The treatment greatly increases the life of apparatus used in heat-treatment operations, such as annealing boxes. Metallurgical information on the subject is to be found in a recent paper by J. Cournot.*

Bars of Armco iron, aluminised commercially, have been tested by immersion in molten "aluminium-bronze" and found to be completely immune from attack. Steel moulds have been similarly treated and show no signs of deterioration on repeated casting. The surface of commercially aluminised steel is variable and has occasionally been found undesirably rough. There should, however, be no difficulty in obtaining a smooth surface, and the variations observed are probably due to the fact that in most aluminised articles a thick surface layer of alloy is required, the surface quality being of little account. The treatment specially given to steel cores and moulds is found to increase the dimensions by about 0.007 in.

Experiments have been made, using for the aluminising medium an alloy of iron and aluminium (50: 50) recommended by Cournot in the Paper referred to above. No difficulty has been found in carrying out the treatment, and very smooth aluminised surfaces have been produced by using very finely ground alloy (140 mesh). Moulds for die-casting test-pieces of various forms have been made from high-carbon steel thinly aluminised. These have not yet shown any indications of wear.

Microscopic Features of the Solution of Materials in Molten Alloy.

Microscopic examination was made of transverse sections of bars which have been subjected to immersion tests in "aluminium-bronze." The section from a chromium-plated steel bar showed good adhesion of the coating, and no indication that the outer surface of the coating had been affected by the molten alloy. Armco iron showed nearly uniform attack. There were, however, numerous points at which solution of the crystal junctions appeared to be slightly in advance of the attack on the crystals. In a bar of 0.64 per cent. carbon steel the surface of attack was irregular, similar in form to that of dendrites, and between the steel and the surrounding mass of "aluminium-bronze" was a thin layer of light-coloured intermediate alloy. Nickel-chromium steel showed a similar irregular dendritic surface, but there was no intermediate layer. The type of interface produced by attack appears to have no relation to the rate of attack, but is more probably connected with the composition and physical characteristics of the immersed material.

In all the cases in which there was no trace of attack by the molten alloy, the surface of the immersed material appeared not to have been wetted; only when attack had occurred did the molten metal adhere to the surface of the bar.

* Rev. Mét., 1926, 23, 219.

Sand and Water.

By Agricomoulder.

An Analogy.

A farmer and a founder have in common that the material they are both using as the foundation of their operations consists of silica grains more or less mixed with clay. Now the clay is a peculiar substance; the state in which it exists in their basic material is vital to both farmers and foundrymen. Briefly, clay may exist in a very finely divided state where the individual particles are almost ultra-microscopic in size, or these very small particles may coalesce together into aggregates easily visible to the naked eye. The farmer wants them to coalesce together; if they stay in the finely divided condition his clayey soil is almost impossible to work; it stays water-logged and cold, the crops are late if they grow at all, and in fact the chief problem of the farmer working on clay soils is to prevent his soil getting into the finely divided state, or, if it does so, to get it as rapidly as possible back into the state in which it is in larger aggregates. Now the foundryman's desires are entirely different. The only purpose the clay serves in the moulding sand is to act as a cement where the sand grains touch one another. The clay is not specially refractory, certainly not as refractory as the silica grains, and if it is not actively increasing the bond in the sand, it is in every way harmful. The colloidal clay cements the sand grains together, the larger aggregates do very little besides blocking up the vents in the moulds.

The Trouble.

In the writer's foundry we have had very grave cause for dissatisfaction with our sand. We have bought the best Mansfield sand (and other kinds which gave no better results), we have milled all the sand in the foundry, we have started afresh with nothing but new sand, and, whatever we have done, invariably after a very short time the sand has been back to its usual condition of very great weakness. The sand washed from the runners of very light castings, small bits of sand stayed down when the cope was lifted from perfect patterns, and so on. The sand had to be made much wetter than we liked for it to have any bond at all, with consequent difficulty in running castings. Altogether we felt that in spite of anything we could do our sand really was a disgrace and not fit for a foundry which was trying to turn out high-class castings. And finally we hit on the trouble.

How the Analogy Helped.

The writer has had a certain amount of farming experience and has read a certain amount of literature on the scientific side of the farming, and at last he started considering the problem not so much from the usual point of view of the iron-founder who wanted the bond in his sand and who expected to get it by regularly adding supplies of new sand, but rather from the point of the farmer who wants intensely to decrease the colloidal clay in his cultivated land. What helps the farmer to get rid of his colloidal clay? Changes of temperature? Well, no one can deny that the changes of temperature in moulding sand are pretty violent. Alternate wetting and drying? Yes, our sand certainly is alternately wet and dried, but why should we get so much more trouble than other people? Sand in other foundries never seems to get into the state ours does in a very short time. Certain chemicals in the soil or in artificial manures? We do not add any chemicals or artificial manures; but, wait a minute, what about the water? Are there any harmful chemicals in that? And there was the trouble!

The Culprit Found.

Our foundry is on the bank of a canal, and for a nominal sum we have been allowed to draw whatever water we wanted from the canal. The water always seemed clear, and we had never thought very deeply about it, and it was distinctly a saving to use the canal water rather than buy water from the corporation at so much per thousand gallons. We did not need any elaborate tests to decide that the canal water had a very great deal to do with the condition of our sand. Three large medicine bottles were partly filled with equal amounts of distilled water, canal water, and the water supplied by the corporation. Into them were inserted equal amounts of new ground Mansfield sand, and they were well shaken. In a few minutes the sand and clay had all settled in the canal water, while the clay remained suspended in the distilled water and the corporation water for many hours. We have not used any more canal water, and our troubles over sand seem to be solved. Certainly the moulders who are paid piecework for good castings seem pleased with the change. We have not investigated the exact nature of the impurities in the canal water that caused our troubles; quite possibly it was an intermitted one through effluents from some works situated on the canal containing acids of some sort. But without spending any more time on it, those three bottles were sufficient to convince anyone that the canal water was highly unsuitable for mixing with moulding sand. So much of the work done on moulding sands is necessarily done under laboratory conditions that it is very easy for such a matter as the purity of the water supply in the foundry to be overlooked. The above test is so simple, however, that it is very easy for any foundryman to make sure that impurities in his water supply are not causing him any trouble. One would anticipate that in some districts where the water supply contains large amounts of temporary hardness it might be profitable for a foundry to install a water-softening apparatus as bicarbonate of lime is one of the most effective agents for changing colloidal clay to its less finely divided form; farmers make use of this fact by spreading lime on clay lands, the lime being converted into bicarbonate by the carbon dioxide in the air.

Catalogue Received.

Dust Removal.—Under the title of "Modern Methods of Dust Removing," Messrs. Brierley, Sons & Company, of School Street, Newton Heath, Manchester, have placed before the foundry world one of its most interesting brochures. It carries with it an inspiration seldom encountered in trade literature. A start is made with the problem of exhausting the dust from grinding wheels, and methods are outlined for meeting the Home Office regulations in a thoroughly workmanlike manner. Rumbers are next considered, and examples are detailed and illustrated, taken from installations made in the foundries of R. and A. Main, Asa Lees, Dobbie Forbes, and Gillespies. An interesting brushing table, as used by Gillespies, of Bonnybridge, and R. and A. Main, in their Falkirk foundry, is described and illustrated. Whilst the heavier sand falls through a grating cushioned with wood slats to prevent breakages, the lighter dust is taken away through chambers connected by pipes to an overhead dust removal system installed at both ends of the table.

A combination grinding wheel guard and dust exhaust hood is another innovation worthy of note.

The final section outlines three methods of dust collecting—dry, wet and the Gutmann system: whilst the last four pages illustrate, *inter alia*, the fettling shops of Ferranti, Falkirk Iron Company, Prince Smith, National Radiator, and the Carron Company.

We advise our readers to avail themselves of the opportunity of procuring a copy of this booklet, which is extremely informative.

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Trade Talk.

MR. C. W. COLEMAN, announces that his telephone number has been changed from Chancery 8165 to Temple Bar 8165.

THE MINISTRY OF TRANSPORT have granted the application of the Mercantile Dry Dock Company, Limited, Jarrow-on-Tyne, for an Order to construct a light railway at the east end of the town.

THE ENGLISH ELECTRIC COMPANY, LIMITED, through their local agents, have successfully tendered for the supply of two 10,000-kilowatt generators to the Victoria State Electricity Commission at a price of £51,600.

CREDITORS OF THE Kryn & Lahy Metal Works, Limited, are required by Mr. A. E. Tilley, the liquidator, 8, Staple Inn, Holborn, London, W.C.1, to send to him particulars of their debts or claims not later than October 1 next.

THE FACT that the German raw steel exports in July exceeded the quota in the Continental Steel Trust has caused the German Steel Ingot Syndicate to ask its members to restrict exports so that for this quarter of the year they may not exceed 900,000 tons.

THIRTY members of the Lancashire Branch of the Institute of British Foundrymen, on the occasion of their visit to the Stafford Coal and Iron Company, Limited, of Fenton, were received by Sir Francis Joseph, C.B.E., and conducted round the works by Mr. E. P. Turner, the general manager of the company.

THE NEWGATE FOUNDRY COMPANY, LIMITED, of Barnard Castle, experienced a severe explosion last Thursday, thought to be due to the presence of a grenade amongst the scrap charged into the cupola. Fortunately, no one was injured.

WILD-BARFIELD ELECTRIC FURNACES, LIMITED, is the new name adopted by the well-known firm of Automatic and Electric Furnaces, Limited. This is the only change to be made. The board of directors and management remain the same. Elecfurn Works, North Road, Holloway, London, N.7, is claimed to be the largest in Europe solely devoted to the manufacture of electric furnaces.

ACCORDING TO THE "Ministry of Labour Gazette," the Admiralty Contract and Purchase Department has placed orders for cast-steel chain cable with Messrs. Cammell Laird & Company, Limited, Sheffield; Hadfields, Limited, Sheffield; and T. Firth & Sons, Sheffield, while the War Office has ordered steel rods from Kayser, Ellison & Company, Limited, Sheffield. Contracts given out by the Crown Agents for the Colonies have been secured by the Staveley Coal & Iron Company, Limited, and H. Bessemer & Company.

THE GRINDING AND Pulverising Offices of International Combustion, Limited, 11, Southampton Row, London, W.C.1, report that orders have recently been received for the following equipment:—For England: One three-roller Raymond mill for grinding titanium; one three-roller "Baby" Raymond mill for grinding colours; one Raymond pulveriser for grinding special earth; one Raymond pulveriser for hydrated lime; and two 4 ft. by 5 ft. electric screens for screening half-ground cement. For France: One three-roller Raymond mill for grinding charcoal; one Raymond pulveriser for hydrated lime; one 4½ ft. by 16 in. Hardinge mill for grinding copper ore.

THE CONFLICT which arose at the beginning of this year between the Georgian Manganese Company, the concessionaire of the manganese fields in the Caucasus, and the Government of the U.S.S.R., and led to the concessionaire's appeal for arbitration, has been settled by an agreement. The main result of this agreement, reached after protracted negotiations, is the Government's consent to the discontinuance of the concession, and to repay within a certain period of time the capital invested by the concessionaire in the enterprise, amounting to several million dollars. At the same time the Government is, it is understood, to be granted by an interested American company a loan for the further development of the manganese industry. The agreement was ratified by the Government in Moscow on August 21, and its final execution is expected soon.

MESSRS. JOSEPH FOSTER & SONS, LIMITED, Soho Foundry, Preston, have secured the complete contract for the power-house installation for the new artificial silk factory now being erected at Stowmarket for the British Acetate Silk Corporation, Limited. The contract includes power house, eight Lancashire boilers, economisers, stokers, coal conveyors and ash-handling plant, pumps, etc. In addition, they have secured the order for boilers, etc., for the extension to the existing power house. The total value of these two contracts amounts to over £41,000. Messrs. Foster have secured other orders for their printing-machine works at Preston and Blackburn, and also for driving machinery required for cotton mills in India, these amounting to over £15,000. The company have on hand at their four works machinery orders to the value of over £255,000.

Reports and Dividends.

Scottish Iron & Steel Company, Limited.—Preference dividend for the half-year at the rate of 6 per cent. per annum, less tax.

Mansfield Engineering Company, Limited.—Loss of £981 for the year ended June 30 last, after making provision for depreciation.

Dalmellington Iron Company, Limited.—Final dividend of 6d. per share on the ordinary shares, making 5 per cent., tax free, for the year.

Brightside Foundry & Engineering Company, Limited.—Profit, £7,868; brought forward, £4,816; preference dividends, £2,250; ordinary dividend of 4 per cent., less tax, £3,200; carried forward, £7,234.

Wellman Smith Owen Engineering Corporation, Limited.—Trading loss for year ended December 31 last, £13,160; provision for taxation, £525. Deducting credit balance brought forward and balance transferred from reserve account, there remains a debit balance on profit and loss account of £10,877 to be carried forward.

R. & W. Hawthorn, Leslie & Company, Limited.—The report for the year ended June 30 states that operations resulted in a loss, but certain tax and other reserves have been transferred to the credit of the profit and loss account, enabling a balance of £20,021 to be shown. To this must be added £17,568 brought forward, making £37,589. Dividend of 3 per cent., less tax, for the year, £21,496; carried forward, £16,093.

Company Meeting.

Brightside Foundry & Engineering Company, Limited.—The annual meeting was held at the works in Sheffield on August 28. MR. F. W. FIRTH, who presided, said they found it increasingly difficult to keep all their departments working satisfactorily, but, considering generally the abnormally bad times, they had not done too badly, and their profits showed an increase. Owing to keen competition, not only abroad but at home, they had been compelled to accept orders at very low prices, and their success had been largely due to the concentration scheme and the strictest economies all round, as it had been impossible to get better prices and any appreciably larger turnover. Their Carbrook works, which they deemed advisable to close down nearly two years ago, were sold at a reasonable figure early in 1928, and they had ample facilities for dealing with any amount of extensions that might arise in the future at their Ecclesfield works when required. They were looking forward with some optimism to the help they would get, not only from the Rating of Machinery Act, but in connection with the new Government rating scheme, and this would also help to increase confidence in the heavy trades. Owing to the altered conditions of trading, they had been compelled to go still further afield for their work, which meant increased expense, and they had had very largely to add to their representation all over the country and abroad.

Pearson and Knowles and Partington Reconstruction Schemes.

An application was made in the King's Bench Vacation Court, on August 29, before Mr. Justice Charles, on behalf of the Partington Steel and Iron Company, Limited, and the Pearson and Knowles Coal and Iron Company, Limited, for the sanction of the Court to a scheme of arrangement and to confirm the reduction of capital. Mr. Luxmoore, K.C., who made the application on behalf of the first-named company, said that the two companies were closely connected, and both were asking for the sanction of the Court.

Following the outline of the scheme for the Partington Company by Mr. Luxmoore, his Lordship sanctioned the scheme of arrangement for that company and confirmed the reduction of capital asked for.

The scheme with regard to the Pearson & Knowles Company was objected to by Mr. Conway, K.C., for certain bond or note holders in that company, and the hearing was adjourned until the following day.

When the Pearson and Knowles Company's petition came before him last Thursday, Mr. Justice Charles approved the scheme and confirmed the reduction of capital. Giving judgment, his Lordship said the scheme fulfilled the requirements laid down in numerous cases. He had studied it clause by clause. There was no coercion and no evidence that the interests of the minority were being overridden by the majority. It appeared to him to be probably the only scheme which could be evolved in the exceptionally difficult circumstances.

Contracts Open.

Angora, September 26.—124,525 kgs. of zinc sheets for the Direction Générale des Fabriques Militaires. The Department of Overseas Trade. (Reference A.X. 6714.)

Belfast, September 17.—Construction of a storm-water pumping station, including pump wells, channels, discharge culvert and super-structure, etc., for the Corporation. Mr. A. Brookes, surveyor, 17, Chichester Street, Belfast. (Fee £5 5s., returnable.)

Bogota (Colombia).—30,000 metres of 12-in. piping (plus 5 per cent. as spares; lap-welded steel, Mannesmann type or riveted); 3,000 metres of 8-in. piping; 500 metres of flexible joint piping, also valves, sleeves, bends, tees, etc., for the Pacific Railway. The Department of Overseas Trade. (Reference A.X. 6718.)

Bushey, Herts., September 11.—Erection of a pumping station and the construction of a 6-in. cast-iron pumping main, for the Urban District Council. Mr. E. E. Ryder, engineer and surveyor, Council Offices, Bushey, Herts. (Fee £2 2s., returnable.)

London, S.E., September 14.—20 tons of white metal for bearings and 18 cwt. of brass sheets (B.E.S.A. No. 265) for the India Stores Department, Belvedere Road, Lambeth, S.E.1. (Fee 5s., not returnable.)

London, E.C., September 17.—Five locomotive boilers, for the Bengal and North-Western Railway Company, Limited, 237, Gresham House, Old Broad Street, London, E.C.2. (Fee 10s., non-returnable.) Overseas Trade. (Reference B.X. 4666.)

London, S.E., September 7.—Copper firebox plates for locomotives for the India Stores Department, Belvedere Road, Lambeth, S.E.1. (Fee 5s., not returnable.)

Salisbury, S.A., October 1.—Supply, delivery and erection of two centrifugal pumps and synchronous induction motors, with starters and switchgear, and one hand-operated travelling crane, for the Municipality of Salisbury, Southern Rhodesia. The Department of Overseas Trade. (Reference A.X. 6717.)

New Companies.

Matbrit, Limited, 229B, Oxford Road, Manchester.—Capital £100. Manufacturers of and dealers in metals, etc. Director: B. Catlow.

Nitralloy, Limited, Norris Deakin Buildings, King Street, Sheffield.—Capital £5,000. Steel manufacturers, converters and refiners, engineers, etc.

Fownes Forge & Engineering Company (1928), Limited.—Capital £10,000. Directors: Mr. L., and Miss D. Macarthy, both of Benwell Park, Newcastle.

Gordon & Munro, Limited, 13-16, Horse Fair, Birmingham.—Capital £20,000. Brassfounders, iron masters, etc. Directors: S. A. Gordon and F. Gordon.

Nelite, Limited, 41, North John Street, Liverpool.—Capital £5,000. Jointing materials for engineering industries, etc. Directors: E. Pelling, F. G. Hasler and H. G. Griffiths.

John Bevitt & Son, Limited, Ropergate, Pontefract, York.—Capital £4,200. Ironfounders, etc. Directors: Annie E. Burton, F. C. Bevitt, H. E. Bevitt, Florence Wooler and Alice Archer.

Joseph Foster & Sons, Limited, Soho Foundry, Greenbank Street, Preston.—Capital £250,000. Engineers, founders and printing machine makers, etc. Directors: J. Y., J. H., and F. Foster.

James Wm. Glover & Sons, Limited, 6-8A, Coventry Road, Warwick.—Capital £6,000. Agricultural implement manufacturers, etc. Directors: J. K. Thompson (permanent director and chairman) and S. Cogswell.

Electric Furnaces, Limited, 17, Victoria Street, London, S.W.1.—Capital £200,000 (100,000 preferred ordinary and 100,000 ordinary), to acquire the business carried on by the Electric Furnace Company, Limited (in liquidation), and to carry on the business of contractors, mining and general engineers, etc. Directors: D. F. Campbell and W. S. Gifford.

Personal.

MR. FRANK BIGGIN, who has completed 46 years' service with the Brightside Foundry & Engineering Company, Limited, Sheffield, has been appointed joint managing director with Mr. F. W. Firth.

WE ARE requested by Mr. Oliver Stubbs to express his very deep sense of gratitude and sincere appreciation for the large number of letters and gifts of flowers he has received from members of the Institute of British Foundrymen during his long illness. Unfortunately, he is not yet in a position to send individual replies, but in the future he hopes to express his thanks personally. Mr. Stubbs has made considerable progress towards recovery, and we trust that the present low speed will accelerate

British Aluminium Casting Alloys.

THE BRITISH ALUMINIUM CO. LTD.,
ALUMINIUM PRODUCERS,
Adelaide House, LONDON, E.C.4.
Telegrams: "Cryolite, Bilgate." 'Phone: Royal 5561.

F.T.J. 7-9-28

No. of Alloy	Specific Gravity.	Melting Point °C.	Test Specimen.	Average Tensile strength Tons/sq. in.	Average Elastic limit Tons/sq. in.	Per cent. Elongation on 2 in.	Remarks.
4	2.75	643	Sand cast	6.5	4.5	4	A light copper alloy which is an admirable substitute for soft brass. Is very ductile, and has a high shock resistance.
			Chill cast	9.5	5.0	8–11	
6	2.98	615	Sand cast	13.0	8.5	4	A copper-zinc alloy which is very strong, easily cast and suitable for general purposes. It has excellent machining qualities.
			Chill cast	13.5	9.0	5	
6a	3.12	600	Sand cast	16.0	12.0	2	Stronger, but heavier than No. 6. Will take a very high polish.
			Chill cast	17.5	11.0	5	
12	2.83	629	Sand cast	7.0	6.0	2	A very reliable non-porous copper alloy. Is largely used for die-castings, as well as for sand castings.
			Chill cast	10.5	7.0	4	
38	2.88	622	Sand cast	9.5	6.0	5	A new copper-zinc alloy which, in view of its high tensile strength, has a remarkable ductility.
			Chill cast	11.5	5.5	13	
50b	2.72	645	Chill cast	9.0	6.5	13	A light nickel alloy which makes hard ductile castings, suitable for mathematical instruments, etc.
40d	2.67	587	Sand cast	11.0	5.0	10	A silicon-aluminium alloy having exceptionally good casting qualities, resistance to corrosion and great ductility.
			Chill cast	13.0	6.0	13	

The above figures are average test results made on specimens cast to 1 in. diameter and machined at the centre to 0.564 in. diameter.

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This is sheet A122 in the B. A. Co.'s Foundry Data.

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GANISTER, CUPOLA BLOCKS, FIRE BRICKS, FIRE CLAY.

Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.

STEEL MOULDERS' COMPOSITION, SILICA CEMENT.

J. GRAYSON LOWOOD & CO., LTD.

DEEPCAR, nr. SHEFFIELD.

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DUNSTON-on-TYNE

"TEAM" PATENT COKE

SPECIAL FOUNDRY QUALITY

FOR PRICE AND PARTICULARS APPLY TO:—

ALEXANDER LEITH & CO.,
25, COLLINGWOOD STREET,
NEWCASTLE-ON-TYNE.

TYPICAL ANALYSIS (if necessary guaranteed)

ASH	not exceeding	8%
SULPHUR	,, ,,	0·8%
VOLATILE	,, ,,	1 %
MOISTURE	under	1·50%

Iron and Steel Markets.

Pig-Iron.

MIDDLESBROUGH.—The virtual suspension of business in the Cleveland iron market during the month just closed has had little effect either way upon the general position of the staple industry of the district, which remains, unfortunately, far from satisfactory as regards both home and export demand. Existing conditions on Tees-side are further complicated by the steadily growing competition of Midland furnaces for orders for foundry material usually placed with Cleveland makers, especially as prices of Midland irons can in some instances be substantially shaded on more favourable terms to buyers. The concessions thus offered have doubtless diverted a considerable share of Cleveland trade in other directions, and as only slow progress has been made in expanding foreign business, the prevailing depression may be readily explained. In the circumstances thus outlined buyers are still inclined to act with great caution, and most of the business put through is of a hand-to-mouth character. In the meantime prices are steady, No. 1 Cleveland foundry iron being 68s. 6d. per ton; No. 3 G.M.B., 66s.; No. 4 foundry, 65s.; and No. 4 forge, 64s. 6d. per ton.

The improvement recently noted in the North-East Coast hematite trade has been sustained. There have been further substantial sales to South Wales, and a few outlets are still to be found in the Italian market. It is now possible to purchase East Coast mixed numbers at 69s., though 70s. is quoted, and No. 1 quality can be bought at 69s. 6d. per ton. On the North-West Coast Bessemer mixed numbers are quoted 68s. per ton at works.

LANCASHIRE.—Notwithstanding some seasonal decline in local markets for foundry pig, prices have been steadily maintained, with Derbyshire No. 3 quoted 67s. to 67s. 6d.; Staffordshire makes, similar quality, about 67s. 6d.; Scottish brands, 87s. to 90s.; and Cleveland, 79s., all per ton delivered Manchester or equal.

THE MIDLANDS.—Foundry buyers throughout the Black Country and adjacent districts continue only quietly engaged, and consequently are limiting purchases within very moderate compass, for which quotations rule as follow:—No. 3 Northampton, 55s.; Derbyshire, 59s. to 60s.; and North Staffordshire on the same level as Derbyshire. Scotch pig-iron is offered at about 87s. per ton delivered locally, but little business is being transacted for this class of iron.

SCOTLAND.—Conditions in this area continue unsatisfactory as regards the local pig-iron industry, foundry demands being unusually poor, stocks at works being ample at present to satisfy current requirements. Quotations are practically unchanged, and makers are exceedingly reluctant to make any concessions, the present range of prices having been in force now for a considerable time.

Finished Iron.

South Staffordshire makers of finished material report only an indifferent volume of inquiries for crown iron, and there is much competition for the relatively small tonnage which is being placed. Prices from Derbyshire, Lancashire and Staffordshire works still vary to a considerable extent, and anything from £9 to £10 is being offered for this quality. There is also great keenness to get what business is passing for nut and bolt iron, which material is quoted from £8 12s. 6d. up to £8 17s. 6d. per ton, while the Belgian product is offered at between £6 17s. 6d. and £7, delivered locally, and although these prices show a considerable advance over the figure quoted a month or so ago, a considerable tonnage is being bought from the Belgian mills.

Steel.

At Sheffield during the current week only a quiet business is passing in the steel market, there being only moderate dealings in acid and basic billets. Of the 90 open-hearth furnaces in the Sheffield area, less than 40 are operating at present. Although foreign competition in cheap material becomes less keen each month, there is no marked improvement in the demand for British steels at the moment, but this development may be expected shortly. Siemens acid billets are unchanged at £10, and the quotations for basic billets are:—Soft, £6 5s.; hard, £7 2s. 6d. to £7 12s. 6d. Wire rod business is on the dull side, with no variation in prices. As regards finished steel, the constructional engineering trades are fairly well employed, and are perhaps the best buyers at the moment. Demand continues slow in the tinplate market, but there are signs of improvement and prospects are fairly bright. More buying has been done, but the works continue to be somewhat short of specifications.

Scrap.

No general improvement can, as yet, be noted in the chief markets for foundry scrap materials, and prices have undergone little, if any, change since last reported. In the North-Eastern area demand continues slow, with heavy cast iron, ordinary quality, quoted 60s. and machinery descriptions 65s. per ton delivered works. In the Midlands there is a better demand for cast-iron scrap, and for heavy machinery cast-iron scrap, broken into cupola sizes, 65s. delivered is offered. For light cast-iron scrap 50s. to 52s. 6d. delivered is realised. At Glasgow machinery cast-iron scrap is still in restricted demand, and it is difficult to find buyers even at 65s. to 66s. Ordinary heavy cast-iron scrap suitable for foundries is quoted 61s., old cast-iron railway chairs 66s. to 67s. 6d., and light cast-iron scrap 57s. 6d., all per ton, delivered f.o.t. consumers' works.

Metals.

Copper.—Consistent steadiness is again a marked feature in the market for warrant copper, with a further upward tendency in evidence. The improvement in the demand from actual consumers has developed a revival in speculative interest, and the immediate trend of values is, therefore, difficult to forecast. The statistical position is, however, unusually strong; there is abundant evidence of steadily increasing consumption both in Europe and America, and, above all, the present price level for standard metal is obviously unnaturally low.

Closing quotations are:—

Cash.—Thursday, £62 11s. 3d. to £62 13s. 9d.; Friday, £62 13s. 9d. to £62 15s.; Monday, £62 12s. 6d. to £62 15s.; Tuesday, £62 16s. 9d. to £62 17s. 6d.; Wednesday, £63 1s. 3d. to £62 2s. 6d.

Three Months.—Thursday, £62 18s. 9d. to £63; Friday, £63 to £63 1s. 3d.; Monday, £63 1s. 3d. to £63 2s. 6d.; Tuesday, £62 18s. 9d. to £63; Wednesday, £63 8s. 9d. to £63 10s.

Tin.—The issue of the August tin statistics, disclosing that the total supplies during that month exceeded all previous records at 12,155 tons, including 9,301 tons from the Straits, has had an unsettling effect upon markets, although qualified to some extent by the fact that deliveries at 11,776 tons were only a little under the highest since March. The prevailing impression in market circles is that, while the tin-consuming trades throughout the world are so exceptionally active, and unless supplies of the metal increase much beyond present expectations, within the next few months it is difficult to see how the market can withstand indefinitely the inevitable increase in buying pressure.

Official closing prices:—

Cash.—Thursday, £212 5s. to £212 7s. 6d.; Friday, £213 5s. to £213 10s.; Monday, £213 10s. to £213 12s. 6d.; Tuesday, £213 10s. to £213 15s.; Wednesday, £210 12s. 6d. to £210 17s. 6d.

Three Months.—Thursday, £208 12s. 6d. to £208 15s.; Friday, £209 to £209 2s. 6d.; Monday, £210 7s. 6d. to £210 10s.; Tuesday, £210 to £210 5s.; Wednesday, £208 10s. to £208 15s.

Spelter.—This section of the market has also developed considerable activity, and although as compared with the volume of inquiry circulating, the actual business passing is still a little disappointing, conditions are now altogether more settled than they were a week or so ago. The improved position has, of course, been reflected in values, which have appreciated steadily from day to day, and at last week's close stood 5s. to 6s. above the opening quotations.

Daily quotations are:—

Ordinary. — Thursday, £24 15s.; Friday, £24 16s. 3d.; Monday, £24 15s.; Tuesday, £24 16s. 3d.; Wednesday, £24 17s. 6d.

Lead.—Interest in the soft foreign pig market still centres in the forthcoming world conference of lead interests and in its probable outcome as regards the control of prices and output. Meanwhile, the improvement in current demand, which became in evidence a week or so ago, is well maintained, and values have been very firm.

Closing prices:—

Soft Foreign Prompt.—Thursday, £22 3s. 9d.; Friday, £22 5s.; Monday, £22 6s. 3d.; Tuesday, £22 8s. 9d.; Wednesday, £22 6s. 3d.

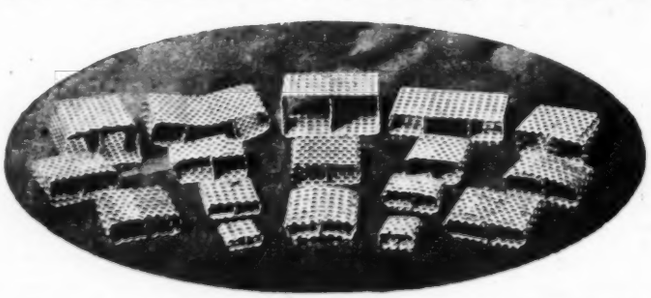
British and American Steel Outputs Compared.—In a report of the National Industrial Conference Board of America, British and American production results are compared. Steel works and rolling mills in Great Britain—we are told—in 1924 employing 200,181 wage earners, turned out $660,895,000 of products, the net output or value added by manufacture representing $195,125,000 of the total. In the United States, in 1925, $2,946,068,000 worth of products were turned out with the relatively small working force of only 370,726, the net output or value added by manufacture amounting to $1,134,107,000. In the British industry 9.15 h.p., in the American mills 12.85 h.p., was at the back of every worker. As a result, production in terms of value added by manufacture in the American steel industry was $3,059 per wage earner employed, as against only $975 per worker in the British mills, or more than three times as much.

WILLIAM OLSEN Ltd., HULL

Chaplet Manufacturers

TINNED STUDS
CHAPLETS
and
PIPE NAILS

SPRIGS



TIN CHAPLETS
(perforated)
EX STOCK or
made quickly to order.

WIRE PINS
(used as Sprigs).

We stock all Goods we advertise.

Sterling

SOLID RIBBED ROLLED STEEL

MOULDING BOXES

are recognised as Standard Box equipment by the majority of the leading foundries and engineering establishments in this country and overseas.

Because they speed up production, save unnecessary labour, produce accurate castings and make for all-round efficiency.

If you are not a user of Sterling Boxes your competitors have the advantage of you.

STERLING FOUNDRY SPECIALTIES LTD.

London Office:
13, VICTORIA STREET, S.W.1.

BEDFORD.

Telephone : 3345 BEDFORD.
Telegrams : "STERFLASK, BEDFORD."
Code .WESTERN UNION.

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash ..	63	1	3
Three months ..	63	8	9
Electrolytic	68	15	0
Tough	65	0	0
Best selected ..	65	5	0
Sheets	94	0	0
India	76	15	0
Wire bars	69	5	0
Do. September ..	69	5	0
Do. October ..	69	5	0
Ingot bars	69	5	0
H.C. Wire rods ..	73	5	0
Off. av. cash, August	62	10	$2\frac{17}{22}$
Do. 3 mths., August	62	18	$11\frac{11}{22}$
Do., Sttlmnt., August	62	10	$4\frac{1}{11}$
Do., Electro, August	69	0	0
Do., B.S., August ..	65	14	2
Aver. spot price, copper, Aug.	62	10	$2\frac{1}{2}$
Do., Wire bars, August	69	5	0
Solid drawn tubes			$13\frac{1}{2}$d.
Brazed tubes			$13\frac{1}{2}$d.
Wire			10d.

BRASS.

Solid drawn tubes	$11\frac{1}{2}$d.
Brazed tubes	$13\frac{1}{2}$d.
Rods, drawn	$10\frac{1}{2}$d.
Rods, extd. or rlld. ..	$7\frac{1}{2}$d.
Sheets to 10 w.g. ..	$10\frac{1}{2}$d.
Wire	$9\frac{1}{2}$d.
Rolled metal	$9\frac{1}{2}$d.
Yellow metal rods	$7\frac{1}{2}$d.
Do. 4 × 4 Squares ..	8d.
Do. 4 × 3 Sheets ..	$8\frac{1}{2}$d.

TIN.

		£	s.	d.
Standard cash ..		210	12	6
Three months ..		210	17	6
English		209	15	0
Bars		213	10	0
Straits ..	(Nom.)	213	0	0
Australian ..	(Nom.)	211	5	0
Eastern		211	15	0
Banca	(Nom.)	218	0	0
Off. av. cash, August		212	19	$10\frac{7}{11}$
Do., 3 mths., August		210	0	$2\frac{7}{11}$
Do., Sttlmt., August		212	19	$1\frac{4}{11}$
Aver. spot, August..		212	19	$10\frac{1}{2}$

SPELTER.

		£	s.	d.
Ordinary		24	17	6
Remelted		23	0	0
Hard		19	10	0
Electro 99.9		28	10	0
English		25	5	0
India		21	5	0
Zinc dust ..	(Nom.)	35	5	0
Zinc ashes		7	15	0
Off. aver., August ..		24	12	$6\frac{15}{44}$
Aver., spot, August..		24	10	$9\frac{1}{2}$

LEAD.

		£	s.	d.
Soft foreign ppt. ..		22	6	3
English		23	15	0
Off. average, August		21	12	$7\frac{4}{11}$
Average spot, August		21	12	8

ZINC SHEETS, &c.

		£	s.	d.
Zinc sheets, English		33	0	0
Do. V.M. ex whf.		31	5	0
Rods		39	0	0
Boiler plates		29	0	0
Battery plates	(Nom.)	30	10	0

ANTIMONY.

		£	s.	d.
Special brands, Eng.		59	0	0
Chinese		39	5	0
Crude		33	10	0

QUICKSILVER.

		£	s.	d.
Quicksilver		23	2	6

FERRO-ALLOYS AND STEEL-MAKING METALS.

		£	s.	d.
Ferro silicon—				
25%	..	8	0	0
45/50%	..	12	0	0
75%	..	19	5	0

Ferro-vanadium—	
35/50%	..14/- lb. Va.
Ferro-molybdenum—	
70/75% c. free ..	..4/3 lb. Mo.
Ferro-titanium—	
23/25% carbonless ..	1/2 lb.
Ferro-phosphorus, 20/25%	£18 0 0
Ferro-tungsten—	
80/85%, c. fr. ..	.. 1/3 lb.
Tungsten metal powder—	
98/99%	1/7 to 1/7½ lb.
Ferro-chrome—	
2/4% car.	.. £30 0 0
4/6% car.	.. £21 7 6
6/8% car.	.. £20 12 6
8/10% car.	.. £20 0 0
Ferro-chrome—	
Max. 2% car. ..	.. £32 15 0
Max. 1% car. ..	.. £37 0 0
Max. 0.70% car. ..	.. £42 0 0
70% carbonless ..	.. 1/- lb.
Nickel—99%, cubes or pellets	£175 0 0
Ferro-cobalt	.. 9/- lb.
Aluminium 98/99% ..	.. £95 0 0
Metallic chromium—	
96/98%	.. 2/8 lb.
Ferro-manganese (net)—	
76/80%, loose ..	.. £13 15 0
76/80%, packed ..	.. £14 15 0
76/80%, export ..	.. £13 15 0
Metallic manganese—	
94/96%, carbonless	.. 1/6 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten	£0 2 3
Finished bars, 18% tungsten	£0 2 9

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over..	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to ⅛ in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ¼ in.	3d. lb.
Do., under ½ in. × ¼ in. ..	1/-lb.
Bevels of approved sizes and sections	6d. lb.
Bars cut to length, 10% extra.	

Scrap from high-speed tool steel—	
Scrap pieces	3d.
Turnings and swarf ..	1d.

Per lb. net, d/d steel makers' works.

SCRAP.

	£	s.	d.	£	s.	d.
South Wales—						
Hvy. steel				3	7	6
Bundled steel and shrngs. ..	3	2	6 to	3	7	0
Mixed iron and steel ..	3	0	0 to	3	2	6
Heavy cast iron	2	15	0 to	2	16	6
Good machinery for foundries				3	2	6
Cleveland—						
Heavy steel				2	15	0
Steel turnings				2	7	6
Cast iron borings ..				2	4	0
Heavy forge				3	10	0
Buehelled scrap				3	0	0
Cast-iron scrap				3	2	6
Lancashire—						
Cast-iron scrap				3	0	0
Hvy. wrought .. .				2	17	6
Steel turnings				2	2	6

London—Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean)	52	0	0
Brass	37	0	0
Lead (less usual draft) ..	18	0	0
Tea lead	15	0	0
Zinc	15	0	0
New aluminium cuttings..	66	0	0
Braziery copper	47	0	0
Gunmetal	47	0	0
Hollow pewter	150	0	0
Shaped black pewter ..	105	0	0

PIG-IRON.

(f.o.t. unless otherwise stated.)

N.E. Coast—	
Foundry No. 1	68/6
Foundry No. 3	66/-
Foundry No. 4	65/-
Forge No. 4	64/6
Hematite No. 1	70/-
Hematite M/Nos.	70/-
N.W. Coast—	
Hem. M/Nos. d/d Glas. ..	79/-
,, d/d Birm.	86/-
Midlands—	
Staffs. common*	67/6
,, No. 4 forge ..	56/-
,, No. 3 fdry... ..	59/6
Shrops. basic	—
,, Cold blast, ord.* ..	—
,, ,, roll iron* ..	—
* d/d Birmingham.	
Northants forge	51/6
,, fdry. No. 3 ..	55/-
Derbyshire forge	59/-
,, fdry. No. 3 ..	59/6
,, basic	60/-
Scotland—	
Foundry No. 1	75/-
,, No. 3	70/-
Hem. M/Nos.	74/-
Sheffield (d/d district)—	
Derby forge	61/6
,, fdry. No. 3 ..	64/-
Lincs. forge	62/6
,, fdry. No. 3 ..	64/-
E.C. hematite	78/6
W.C. hematite	84/-
Lincs. (at furnaces)—	
Forge No. 4	58/-
Foundry No. 3	59/6
Basic	—
Lancashire (d/d eq. Man.)—	
Derby forge	—
,, fdry. No. 3 ..	67/6
Northants foundry No. 3..	—
Dalzell, No. 3(special)	100/- to 102/6
Summerlee, No. 3	87/- to 90/-
Glengarnock, No. 3	87/- to 90/-
Gartsherrie, No. 3	87/- to 90/-
Monkland, No. 3	87/- to 90/-
Shotts, No. 3 ..	87/- to 90/-

FINISHED IRON AND STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

	£	s.	d.	£	s.	d.
Iron—						
Bars (cr.) nom.	9	10	0 to	10	15	0
Nut and bolt iron	8	12	6 to	8	17	6
Hoops				11	10	0
Marked bars (Staffs.) f.o.t.				12	0	0
Gas strip				11	10	0
Bolts and nuts, ¾ in. × 4 in.				15	5	0
Steel—						
Ship plates..	8	7	6 to	8	12	6
Boiler plts...				10	10	0
Chequer plts.				10	12	6
Angles				7	17	6
Tees				8	17	6
Joists				7	17	6
Rounds and squares, 3 in. to 5½ in.				8	17	6
Rounds under 3 in. to ¼ in. (Untested)				7	15	0
				and upwards		
Flats, over 5 in. wide and up				8	7	6
Flats, 5 in. to 1½ in. ..				7	17	6
Rails, heavy				8	10	0
Fishplates				12	10	0
Hoops (Staffs.)				10	0	0
Black sheets, 24g. ..				10	0	0
Galv. cor. shts., 24g. ..				13	10	0
Galv. fencing wire 8g. plain				12	10	0
Billets, soft	6	2	6 to	6	10	0
Billets, hard	7	2	6 to	7	12	6
Sheet bars				6	0	0
Tin bars				6	0	0

PHOSPHOR BRONZE.

	Per lb. basis.
Strip	1 2½
Sheet to 10 w.g.	1 3
Wire	1 3½
Rods	1 3
Tubes	1 7½
Castings	1 2

Delivery 3 cwt. free.
10% phos. cop. £40 above B.S.
15% phos. cop. £50 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	per lb.
Ingots for raising ..	9d. to 1/3
Rolled—	
To 9 in. wide ..	1/3 to 1/9
To 12 in. wide ..	1/3½ to 1/9½
To 15 in. wide ..	1/3½ to 1/9½
To 18 in. wide ..	1/4 to 1/10
To 21 in. wide ..	1/4½ to 1/10½
To 25 in. wide ..	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
3/0 to 10 G.	1/6½ to 2/1½

with extras according to gauge.

AMERICAN IRON AND STEEL.

At Pittsburgh unless otherwise stated.

	Dols.
No. 2X foundry, Phila. ..	20.26
No. 2 foundry, Valley	16.50
No. 2 foundry, Birm.	15.50
Basic	17.76
Bessemer	18.76
Malleable	18.76
Grey forge	18.01
Ferro-mang. 80% d/d	105.00
O.-h. rails, h'y at mill	43.00
Bess billets	32.00
O.-h. billets	32.00
O.-h. sheet bars	32.00
Wire rods	42.00
	Cents.
Iron bars, Phila.	2.12
Steel bars	1.90
Tank plates	1.90
Beams, etc.	1.90
Skelp, grooved steel	1 90
Skelp, sheared steel	1.90
Steel hoops	2.20
Sheets, black, No. 24	2.65
Sheets, galv., No. 24	3.40
Sheets, blue an'l'd., 9 and 10 ..	2.00
Wire nails	2.55
Plain wire	2.40
Barbed wire, galv.	3.20
Tinplates, 100 lb. box	$5.25

COKE (at ovens).

Welsh foundry	—
,, furnace	19/- to 21/-
Durham and North.	
,, foundry	14/- to 14/6
,, furnace	14/-
Other Districts, foundry ..	—
,, ,, furnace (basis) ..	12/-

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. Cokes ..	20×14 box	18/- to	18/3
,, ..	28×20 ,, ..		36 3
,, ..	20×10 ,, ..		27/-
,, ..	18½×14 ,, ..		18/9
C.W.	20×14 ,, ..		16/-
,, ...	28×20 ,, ..		33/6
,, ...	20×10 ,, ..		22/-
,, ...	18½×14 ,, ..		15/9
Terneplates ..	28×20		33/6 per box basis f.o.b.

SWEDISH IRON.

Bars, hammered, £17 10 0 to £18 10 0	
Rolled Ord. ..£15 0 0 to £15 10 0	
Nail rods .. £15 7 6 to £15 15 0	
Keg. steel nom.	£33 to £35
Faggot steel nom. ..	£22 to £25
Blooms, according to quality	£8 to £12
Pig-iron .. £5 15 0 to £6 0 0	

all f.a.b. Gothenburg.

TUBES AND FITTINGS.

Up to and incl. 6 in.

	Tubes.	Fittings.
Gas	67½%	50%
Water	63½%	45%
Steam	60%	40%

W.I. 10% extra.

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£ s. d.	
Aug. 30	62 11 3	inc. 2/6
,, 31	62 13 9	,, 2/6
Sept. 3	62 12 6	dec. 1/3
,, 4	62 16 3	inc. 3/9
,, 5	63 1 3	inc. 5/-

Electrolytic Copper.

	£ s. d.	
Aug. 30	68 15 0	No change
,, 31	68 15 0	,, ,,
Sept. 3	68 15 0	,, ,,
,, 4	68 15 0	,, ,,
,, 5	68 15 0	,, ,,

Standard Tin (cash).

	£ s. d.	
Aug. 30	212 5 0	inc. 52/6
,, 31	213 5 0	,, 20/-
Sept. 3	213 10 0	,, 5/-
,, 4	213 10 0	No change
,, 5	210 12 6	dec. 57/6

Tin (English ingots).

	£ s. d.	
Aug. 30	210 10 0	inc. 60/-
,, 31	211 5 0	,, 25/-
Sept. 3	211 10 0	,, 5/-
,, 4	211 10 0	No change
,, 5	209 15 0	dec. 35/-

Zinc Sheets (English)

	£ s. d.	
Aug. 30	33 0 0	No change
,, 31	33 0 0	,, ,,
Sept. 3	33 0 0	,, ,,
,, 4	33 0 0	,, ,,
,, 5	33 0 0	,, ,,

Spelter (ordinary).

	£ s. d.	
Aug. 30	24 15 0	No change
,, 31	25 2 6	inc. 7/6
Sept. 3	24 15 0	dec. 7/6
,, 4	24 16 3	inc. 1/3
,, 5	24 17 6	inc. 1/3

Lead (English).

	£ s. d.	
Aug. 30	23 10 0	No change
,, 31	23 10 0	,, ,,
Sept. 3	23 15 0	inc. 5/-
,, 4	23 15 0	No change
,, 5	23 15 0	,, ,,

AVERAGE MONTHLY PRICES OF WEST COAST HEMATITE MIXED NUMBERS DELIVERED SHEFFIELD.

Year.	Jan	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Yearly Average.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1888	44 4	42 3	42 1½	42 0	41 2½	42 1½	42 6½	44 0	45 8½	44 5	44 6	45 3½	43 4
1889	44 4	45 2	47 3½	48 9½	48 6½	48 7½	50 1½	53 11	55 3	63 6	73 10	73 2	54 4½
1890	76 1½	65 1	63 3	55 1	53 9½	50 11	52 3½	56 4	58 0	58 2	57 5	54 4½	58 5
1891	52 9	50 10	48 11	47 9½	51 5	50 6	50 10	48 4	50 1	49 1½	48 3½	47 8	49 8½
1892	47 4	45 6	46 4½	47 8	49 5	50 4½	49 7½	49 10½	49 10½	48 8½	46 10	46 1½	48 2½
1893	46 0½	45 8	45 11	45 7	44 11	44 9½	44 10	45 3	45 0	44 6	44 7	45 8	45 3
1894	45 3	45 3	45 1½	45 1	43 11	43 11	43 9½	44 2	44 7½	43 7	43 5	43 3	44 3½
1895	42 8	42 5½	42 6	42 10	43 10	43 7½	44 10	45 11	49 11	48 9	47 7½	47 7½	45 2½
1896	47 0	48 9	48 9	48 2½	47 3	47 3	46 10	46 10	47 2	48 5	50 7	50 6	48 1½
1897	51 2	49 10	48 5	47 4	47 9½	48 6	47 0	47 3	47 3	47 0	48 3½	47 11	48 2
1898	48 9	48 10	49 4	49 8½	50 10	50 3½	51 0	52 5	53 11	55 8	57 3	56 10	52 1½
1899	59 1	59 9	57 7	59 6	64 7	70 10½	76 7½	72 2	74 3	75 0	78 1½	73 3	68 5
1900	75 3½	76 10	79 10	84 6	81 4	79 1½	83 4	81 5	79 11	76 10	77 8½	68 4	78 8
1901	60 2	59 0	57 9½	57 6½	57 8	57 4½	57 8	61 0	60 0½	59 9	58 7½	56 7	58 7½
1902	56 1	57 9½	59 3½	59 9	59 10½	60 0	60 0	60 8½	61 5	61 2	59 3	59 0	59 6
1903	58 5	58 8	61 1	59 5	57 10	57 3	56 7	56 3	55 9	54 8	52 4	52 4	56 8½
1904	52 8½	53 1	53 7	54 9	54 2	53 2½	52 9	52 5	52 2½	52 7	53 1	55 11½	53 5½
1905	57 9½	56 9	58 1	58 2	56 4	55 8	55 5½	56 7	61 0	68 9	69 9	70 11½	60 5½
1906	70 4½	65 2½	63 4½	63 9	64 5	64 6	64 1	66 2½	67 3	69 4½	72 4½	78 8½	67 5
1907	77 9	72 11	71 10	73 9	79 9½	76 9	77 9	78 4	75 11	72 9½	68 6	66 7	74 4
1908	62 7	59 1	61 6½	61 6½	61 4	59 1	57 9½	56 11	60 2	59 2	58 5½	57 7	59 7½
1909	51 4	56 5	55 3	56 1	56 4	57 0	56 8	58 0	61 0	61 1½	60 7½	61 4	58 1½
1910	64 0½	64 3½	66 10½	67 6½	66 2½	65 4	64 4½	65 6½	65 2	64 10½	64 6	65 6	65 4½
1911	66 9	66 1	64 10	63 1	62 1	62 0	61 2	62 2	62 1	61 1	61 10	64 0	63 1
1912	67 0	67 0	67 0	69 3	71 9½	72 11	75 9½	79 1½	82 2½	85 0	85 3½	86 6	75 9½
1913	86 6	86 6	86 3	85 0	83 6½	80 10½	78 1	76 10½	72 6	71 0	68 0	65 3	78 4½
1914	64 6	65 4½	65 6	64 11½	64 2½	64 0	64 0	68 11½	74 6½	71 0	65 4½	69 9½	66 10½
1915	78 9	100 6	103 1	113 6	111 9	114 0	116 3	115 2½	113 8½	121 1½	131 9½	139 6½	113 3
1916	135 0	135 0	133 4	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	129 2½
1917	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1918	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1919	127 6	127 6	127 6	127 6	180 6	184 3	195 4½	204 6	204 6	204 6	204 6	204 6	174 7
1920	224 9	235 0	245 0	275 0	290 0	295 0	295 0	295 0	295 0	295 0	295 0	280 0	284 11½
1921	263 4	228 4	180 0	180 0	180 0	160 0	160 0	157 6	142 0	128 6	121 0	115 6	167 9½
1922	125 0	117 6	115 0	115 0	115 0	115 0	113 1½	104 0	105 0	105 0	106 3	110 0	112 1½
1923	109 0½	116 5½	133 11½	138 3½	134 2	125 0	115 7½	111 9	110 0	110 0	113 11	115 0	119 5½
1924	115 0	115 0	114 4½	112 6	112 6	112 6	111 0	110 0	110 0	105 4½	102 6	102 6	110 3½
1925	102 6	102 6	100 0	98 6	97 6	95 1½	92 6	90 6	88 3	87 0	88 1½	88 9½	94 3½
1926	90 1½	90 0	89 8½	89 0	89 0	89 0	90 2½	91 9	94 0	97 2½	*	*	91 9
1927	95 4½	95 6	96 6	95 6	95 3	94 0	92 10½	91 6	90 6	90 6	90 6	89 6	93 1½
1928	85 0	85 3	85 5	85 0	85 3	84 9	84 0	83 9	—	—	—	—	—

* No prices available

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